Final Project Report: Conservation Innovation Grant

Title of the grant or project:
Drought Mitigation for Beef Cattle Producers Using Native Grasses in Grazing Systems and as Alternative Feedstocks for Confined Feeding

Name of the principal investigator or project manager:
Jane A. Parish, Research/Extension Professor, North Mississippi Research and Extension Center Prairie Research Unit, Prairie, MS (finished project initiated by Holly T. Boland)

Timeframe covered by the report:
36 months: June 1, 2014 to May 31, 2017
A one-year time extension on the project was approved by the UDSA NRCS in 2014. As a result, all timeline goals slid forward one year from the original timeline.

Grant number:
69-3A75-13-94

Date of submission:
October 15, 2012

Deliverables identified on the grant agreement:

- Project progress reports
- Final report at project completion (the current report)
- Fact sheet/extension publication about the demonstration project
- Two workshops based on this project held at the Prairie Research Unit
- Supplemental narrative(s) that explain and support payment requests
- Participation in at least on NRCS sponsored event (criteria met by workshops listed above)

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Executive Summary

This project was designed to address the issue that current mainstream beef cattle grazing production practices do not utilize drought-tolerant forages. Native grasses may be used in drought mitigation strategies, but adoption of these forages requires evidence of other production benefits. Native warm-season grasses including big bluestem, little bluestem, and indiangrass were compared to a widely used improved forage, bermudagrass, in stocker cattle grazing and confined feeding scenarios. Likewise, the native cool-season grass, Virginia wildrye, was compared with commonly used improved cool-season grasses, annual ryegrass and wheat in stocker cattle nutrition programs. Forage nutritive values of native grasses were comparable to improved forages. Stocker cattle growth as measured by rate of weight gain was comparable in native grasses relative to improved grasses. Stocking rate did not influence stocker calf average daily gain on warm-season native grasses. These findings were shared with academia and industry participants via publications and presentations. Questions remain on agronomic traits including stand establishment best management practices and risks and long-term persistence of native grass forage stands under commonly used grazing management practices. Production economics concerns including stand establishment challenges and seed costs may slow adoption of native grasses into beef production systems unless further systems research shows an economically advantageous series of production practices that includes native grasses. Further, extreme wet conditions as are common in the Southeast U.S. and native grass productivity and survival under those conditions warrants study.

Introduction

This study was designed to evaluate the use of native grasses relative to improved grasses in beef stocker production systems to determine their value for drought mitigation. It was conducted at the Prairie Research Unit in Prairie, MS. The Prairie Research Unit is a branch experiment station of the North Mississippi Research and Extension Center and is part of the Mississippi Agricultural and Forestry Experiment Station. This project was implemented by the resident scientist and staff at the Prairie Research Unit to include Dr. Jane Parish, Tim Best, Cheyenne Stewart, Bobby Bates, Monty McIlwain, Robert Duke, Robert Dobbs, Dennis Herndon, Wesley Rogers, and Joyce Pace.

Warm-season native grasses evaluated include indiangrass, big bluestem, and little bluestem were compared as grazing and baleage fed to steers versus bermudagrass. In addition, three stocking rates on a mix of indiangrass, big bluestem and little bluestem were compared to develop appropriate stocking rate recommendations on this pasture. The native cool-season grass, wild rye, were compared with the improved cool-season grass, annual ryegrass, as both pasture and baleage. The scientific literature is currently inadequate with regard to the forage comparisons made in this study, thus necessitating this study to determine this information.

Project objectives were as follows:
Objective 1: To demonstrate the use of three summer grazing systems, two of which use drought tolerant native warm season grasses (1) indiangrass monoculture pastures and (2) mixed species pasture of indiangrass, big bluestem, and little bluestem; with the third grazing system using the most common summer forage in this region, the non-native (3) bermudagrass.
Objective 2: To demonstrate the impact of different cattle stocking rates in a grazing system incorporating drought-tolerant mixed species pasture of indiangrass, big bluestem, and little bluestem.
Objective 3: To demonstrate the use of drought tolerant feedstocks in the form of conserved native warm-season grass baleage as an option to feed to beef cattle in confined feeding operations during winter months.

Objective 4: To demonstrate the use of conserved cool-season forage baleage as an option to feed to beef cattle in confined feeding operations during summer when drought has reduced or eliminated pasture availability.

This project was funded by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) as a Conservation Innovation Grant (NRCS Grant Agreement Number: 69-3A75-13-94). Cost share was provided by the Mississippi Agricultural and Forestry Experiment Station.

Background

The excessive droughts that have plagued the United States for the past several years have forced us to look for alternatives to what have become traditional methods of beef cattle production. Current production practices generally do not utilize drought tolerant forages and feedstocks so when droughts occur there are drastic shifts in both feed and cattle commodity markets. As pastures dry up and forages become unproductive or die, cattle producers are forced to provide supplemental feed, sell animals, or both. Those same drought conditions will also impact commodity feed production, such as corn or soybeans, by decreasing yields. As commodity feed supply goes down, prices go up and producer costs can skyrocket. Confined feeding operations feed corn-based rations to cattle so the shifts in supply of corn during drought also impact this segment of the beef cattle industry. Native grasses are the forage species that were growing here in the U.S. prior to European colonization. The early settlers brought in non-native forage species that were extremely invasive and many of the native forages were forced to the brink of extinction. There is currently a renewed interest in reestablishing these native forages in grasslands and utilizing them for beef cattle production. Native grasses can fit into this production system very well because they are extremely drought tolerant, highly productive, and have low fertilization input requirements. As an added benefit they provide excellent ecosystem services such as habitat for wildlife and carbon sequestration.

There has been considerable effort in researching native grasses and it has been shown that incorporation of these forages into beef cattle production systems can provide excellent animal performance while also being cost effective, mainly due to lower input requirements. Many beef cattle producers, however, are hesitant to move away from the non-native forages which they are currently using, such as bermudagrass, because this has become their traditional production practice. In order to achieve producer adoption the use of native grasses for beef cattle production needs to be presented to them in a local context illustrating the drought mitigation potential.

This demonstration looks at the use of native grasses in several scenarios to illustrate how they can be used for drought mitigation in beef cattle and forage production systems. In the first objective, the use of three summer grazing systems is demonstrated, two of which use drought tolerant native warm-season grasses (1) indiangrass monoculture pastures and (2) Mixed-species pasture of indiangrass, big bluestem, and little bluestem; with the third grazing system using the most common summer forage in this region, the non-native (3) Bermudagrass. Secondly, this project demonstrates the use of different cattle stockings rates in a grazing system incorporating drought tolerant mixed-species pasture of indiangrass, big bluestem, and little bluestem. Thirdly, it demonstrates the use of drought-tolerant feedstocks in the form of conserved native warm-season grass baleage as an option to feed to beef cattle in confined feeding operations during winter months. Fourthly, it shows the use of conserved cool-season forage baleage as an option to feed to beef cattle in confined feeding operations during summer when drought has reduced or eliminated pasture availability. This project meets the goals of the Conservation Innovation Grant program by the development of a promising system of drought mitigation through the use of native forages which are demonstrated, evaluated, and monitored through periodic measures of productivity and performance through implementation on a production scale.

Review of methods

Warm-season grasses (Objectives 1 and 2)

Pastures of bermudagrass, indiangrass and mixed-sward native warm-season grasses (mix of big bluestem, little bluestem, and indiangrass) previously established at the Prairie Research Unit were utilized in this project. Refer to Monroe et al. (2017) for detailed methods of forage establishment. Briefly, both the indiangrass and mixed-sward pastures of native warm-season grasses were planted in May and June 2009 using 8 lbs/acre of pure live seed.

Beef stocker calves grazing native warm-season grasses at Prairie, MS during this project

Cool-season grasses

Three cool-season forage grasses: annual ryegrass (ARG), wheat (WHT), and Virginia wildrye (VWR) were compared for forage nutritive value and steer growth performance for 2 yr at the North Mississippi Research and Extension Center Prairie Research Unit at Prairie, MS (latitude 33.7891oN; longitude 88.6585oW; elevation 100 m). This grazing experiment was a randomized complete block design. There were 9 total pastures: 3 pasture treatments with 3 replications of each pasture treatment randomly arranged in 3 blocks. Soil type was Houston clay. The 2.17-ha pastures were clipped to 3-cm stubble height in mid-August each year. After volunteer grass seedlings emerged in late August, an application of glyphosate (1.5 L/ha of 41% vol/vol) was applied to eradicate the existing pasture species. On September 17 to 19, 2014 and September 16 to 18, 2015 the Virginia wildrye (2014 planting only), annual ryegrass, and wheat seed were no-till drilled at seeding rates of 16.8, 33.6, and 112.1 kg/ha, respectively. Nitrogen (27.2 kg N/ha) was applied as ammonium nitrate 2 wk after seedling emergence from the soil in October each year. Soil test results indicated that lime, phosphorus (P), and potassium (K) applications were not necessary.

Cattle and grazing management (Objectives 1 and 2)

The cattle in this experiment were managed under protocol 14-050 approved by the Mississippi State University Institutional Animal Care and Use Committee. Weaned British crossbred calves (steers for Objective 1 and heifers for Objective 2) (mean initial body weight ± standard error = 276 ± 10.4 kg) less than 1 year of age were acquired from the resident Mississippi Agricultural and Forestry Experiment Station herd at Prairie, MS. Cattle were of comparable breed composition, age, and BW. Before each grazing season, calves were vaccinated for protection against respiratory disease complex with Pyramid 10 (Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO), against Clostridial diseases with Vision 7 (Intervet, Inc.; Millsboro, DE), and against Mannheimia diseases with Presponse SQ (Fort Dodge Laboratories, Inc.; Fort Dodge, IA). Cattle were also treated for internal and external parasites with

EPRINEX pour-on (Merial; Duluth, GA) at a dosage rate according to the product label and applied an XP 820TM insecticide fly tag (Y-Tex Corporation, Cody, WY) in 1 ear per steer at grazing initiation.

The cattle were grazed together on mixed sward cool-season grass pasture for 14 days before being stratified by body weight and breed composition to experimental paddocks at the beginning of each grazing season. Four steers per paddock were used each grazing season. These steers remained on their original assigned experimental paddocks for the duration of the grazing season. In each paddock, cattle were supplied at all times with access to fresh water and free-choice mineral supplement (Purina Wind & Rain Storm Fescue Hi Mag 5 CO AU2800 Medicated; Purina Animal Nutrition LLC, Shoreview, MN) containing 3.09 g/kg of chlortetracycline, 13.5% Ca, 5.0% P, 18.0% salt (NaCl), 10.0% Mg, 0.1% K, 4,800 mg/kg of Mn, 4,800 mg/kg of Zn, 1,600 mg/kg of Cu, 80 mg/kg of I, 16 mg/kg of Co, and 27 mg/kg of Se. The mineral supplement was labeled to contain 661,386.8 IU of vitamin A/kg, 66,138.7 IU of vitamin D/kg, and 661.4 IU of vitamin E/kg.

For the warm-season experiment, summer grazing seasons were 56 days each. Grazing periods for the year were as follows: June 3 to July 29, 2015 and June 1 to July 27, 2016, for the warm-season experiments with the calves grazing the pastures for the entire duration of these grazing periods. For the cool-season experiment, spring grazing seasons were 56 days each. Grazing periods for the year were as follows: April 8 to June 3, 2015 and April 6 to June 1, 2016, for the cool-season experiment with the calves grazing the pastures for the entire duration of these grazing periods. Continuous stocking management was utilized. Paddocks were restocked with new animals at the beginning of each grazing season. Between grazing periods during August each year, paddocks were mechanically clipped.

Pasture data collection

Paddocks were measured every 28 days beginning day 0 through the end of each grazing season to monitor herbage mass using a double-sampling technique. The sward height was measured using a falling plate disk meter with 50 contacts per paddock. In each paddock, the first disk meter contact site was selected by walking a randomly selected number of steps into the pasture from the gate. Thereafter, a fixed number of steps, estimated to cover 5 diagonal transects in a zigzag pattern in each paddock, were used to determine the rest of the contact sites so as to spatially cover the entire paddock. After taking disk measurements in each paddock, herbage from three 0.25-m^2 quadrats were harvested at 2.5 cm above the soil surface at sites selected to approximate the shortest, mean, and tallest disk meter readings recorded in the paddock in order to calibrate the indirect estimates (disk meter readings) with direct estimates (harvested herbage samples). The quadrat cuts from each paddock were weighed fresh and then pooled within grazing paddock within pasture replicate. From each pooled sample, a 1-kg sub-sample was taken, dried in a forced-air oven at 60°C for 72 hours, and then weighed in order to determine dry matter concentration. A regression equation was developed for each sampling date with direct measurements (dry matter weight of clipped samples) as the dependent variable and indirect estimates (disk readings) and the independent variable. Herbage mass was then estimated with the resulting regression equation using the mean of the 50 disk readings per paddock. Season average herbage mass was calculated as the mean of all herbage mass estimates taken within each season.

Subsamples of the pooled herbage samples from day 0, 28, and 56 of the grazing period were frozen at -20 degrees C, lyophilized, ground through a 1-mm screen in a Wiley mill (Arthur A. Thomas; Philadelphia, PA), and shipped to Dairy One Forage Lab (Ithaca, NY) to be analyzed for nutritive value including dry matter, total digestible nutrients (TDN), acid indigestible neutral detergent fiber (aNDF), acid detergent fiber (ADF), and total nitrogen (N). Crude protein concentration was determined by multiplying total nitrogen concentration as determined by combustion by 6.25.

Calf data collection
Calf body weigths were collected at the onset of each grazing season and 28-day intervals, thereafter. Initial and final unshrunk calf body weights were collected on 2 consecutive days and averaged. Animal days for each pasture were calculated as the sum of the days each calf spent grazing the pasture during a given grazing season. Calf average daily gain (ADG) was computed by dividing mean body weight gain in a particular paddock by the number of days in the grazing season. Mean stocking rate was computed by dividing steer days by the duration of the grazing season in days and then multiplying by the mean animal body weight. Mean herbage allowance was calculated as the quotient of mean herbage mass divided by mean stocking rate. Body weight gain/hectare was calculated as the number of animal days multiplied by calf average daily gain. For 28-day periods, the previously described calculations were utilized, but instead of considering the entire grazing season, only data from the particular 28-day period of interest was used.

Confinement feeding of conserved forages (Objectives 3 and 4)
Fields of annual ryegrass and Virginia wildrye were established at the North Mississippi Research and Extension Center Prairie Research Unit in Prairie, MS in September 2014 (and again in September 2015 for the second year of annual ryegrass production) for the purpose of ensiled forage production. Fields were precision drilled and fertilized as described for the cool-season grazing experiment. The warm-season conserved forage experiment utilized existing fields of bermudagrass and native warm-season mixed grass as described for the warm-season grazing experiment.

At harvest in May of 2015 and 2016, moisture of cut forage was monitored using a moisture meter (Windrow Hay Moisture Tester; AgraTronix, LLC, Streetsboro, OH) to target baling forage at approximately 50% moisture. Forage was cut using a rotary disk mower (GMD 310; Kuhn North America, Inc., Brodhead, WI), raked, and baled into large round bale packages (John Deere 557 Round Baler; John Deere, Moline, IL). These bales were immediately individually encased with 21 wraps per bale of a white plastic (Tytan silage wrap; Tytan International LLC, Lenexa, KS) to create an anaerobic environment for ensiling and then stored either outdoors or in open-air barns until feeding.

Example wrapped bale of warm-season native grass used in this project

Example wrapped bale of Virginia wildrye used in this project

Forage intake and feeding behavior was monitored using a GrowSafe Model 6000® feed intake and behavior monitoring system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada) at the North Mississippi Research and Extension Center Prairie Research Unit in Prairie, MS. Twenty-four weaned British crossbred steers less than 1 yr of age from the resident Mississippi Agricultural and Forestry Experiment Station herd at Prairie, MS were allocated to this experiment each year in Spring 2015 and 2016. Vaccination and animal health treatments of steers were the same as in Experiment 1. There were 3 steers per pen across 8 pens, and each pen contained 2 GrowSafe feed nodes in which forage was offered to the steers ad libitum. A 14-day warm-up period was utilized to acclimate the steers to consuming forage in the GrowSafe feeding system prior to the start of the trial. Steers were weighed unshrunk on 2 consecutive days at the beginning and end of the trial and initial and final weights averaged, respectively.

For the warm-season project (Objective 3), in four of the GrowSafe pens, steers were offered mixed native warm-season grass conserved as ensiled forage; in the other four GrowSafe pens steers were offered bermudagrass conserved as ensiled forage. For the cool-season project (Objective 4), in four of the GrowSafe pens, steers were offered Virginia wildrye conserved as ensiled forage; in the other four GrowSafe pens steers were offered annual ryegrass conserved as ensiled forage. At feeding, plastic wrap and twine were removed from individual bales, and bales were chopped in a bale processor (BPX9000, Vermeer Corporation, Pella, IA) for ease of feeding. The ensiled forage was then delivered to the GrowSafe bunks by hand feeding at least once daily and more frequently as needed to ensure ad libitum forage access at all times during the trial. Bunks were cleaned approximately once per week or as needed to remove feed refusals or forage that had packed on the floor of the bunks and immediately refilled with freshly processed ensiled forage.

All steers were offered ad libitum access to a loose mineral supplement contained in a separate feed trough in each pen. The mineral supplement (Purina Wind & Rain Storm All Season 7.5CP AU5600 Altosid Medicated; Purina Animal Nutrition LLC, Shoreview, MN) was labeled to contain 6.17 g/kg of chlortetracycline, 0.14 g/kg of S-methoprene, 13.5% Ca, 7.5% P, 18.0% salt (NaCl), 1.0% Mg, 1.0% K, 3,600 mg/kg of Mn, 3,600 mg/kg of Zn, 1,200 mg/kg of Cu, 60 mg/kg of I, 12 mg/kg of Co, and 27 mg/kg of Se, 661,386.8 IU of vitamin A/kg, 66,138.7 IU of vitamin D/kg, and 661.4 IU of vitamin E/kg. Steers were supplied with fresh water at all times via JUG Model 202 water troughs (Bakko Industries, Inc., Glenwood, MN) in each pen. Pens were 7.6 m x 22.6 m in area including a concrete floored area under a shed providing shade at all times where the GrowSafe feed nodes were contained and an adjoining dirt-floored drylot area outside the shed. Overhead fans were used to circulate air in the shed.

Statistical analysis
The MIXED procedure of SAS (SAS Institute Inc., Cary, NC) was used to analyze continuous data from the experiment, whereas PROC GLIMMIX was utilized to analyze data expressed as percentages including forage nutritive value traits. A randomized complete block experimental design was used with paddock or pen as the experimental unit. Main effects were forage species, grazing period, and grazing year. The model included main effects and their interactions. Forage species effects were tested using paddock or pen within forage species as the error term. Period effects and period × forage species were tested using period × paddock or pen within forage species as the error term. Because block was not a significant source of variation, and there were no significant interactions involving block, means were pooled within treatment across blocks. Means were separated at $P < 0.05$ using the PDIFF function of SAS.

Project outreach efforts
Outreach accomplishments exceeded the required two workshops based on this project. First, a cattle and forage field day and workshop took place at the Prairie Research Unit in Prairie, MS for October 25, 2014 to engage the public as the project launched the initial months of this research effort. A second field day and workshop was held at the Prairie Research Unit on October 1, 2016 as the project approached research completion (http://extension.msstate.edu/calendar/day/2016-10-01/prairie-research-unit-fall-beef-cattle-field-day). The public was invited to each of these field day and workshop events. An update on this native grass research project was presented at the field day, and participants toured the grazing paddocks. Social media was used to promote workshops and this project via the Twitter account @msuprairie.

Field day (workshop) advertisement examples for this project

In addition to the two workshops included in the project deliverables, the project results were also incorporated into the Mississippi Cattlemen's Association Cattlemen's College hosted at the Prairie Research Unit on September 23, 2015.

Field day flyer and participants at the Prairie Research Unit on September 23, 2015

A tour group of Missouri cattle producers also visited the Prairie Research Unit on August 4, 2015 and were educated on the project during that site visit. The Monroe County Cattlemen's Association (Monroe County, MS) met at the Prairie Research Unit on May 5, 2015 and learned about the project during that meeting and site tour.

Missouri cattle producers at the Prairie Research Unit on August 4, 2015

Mississippi State University Extension now has a series of fact sheets on native grass establishment and grazing management based upon the initial interest in this topic generated by the proposal developer. Fact sheet/extension publications are listed in the Technology Review Criteria section of the current document.

Discussion of Quality Assurance

The following steps were taken to ensure that data from the project are valid. The project site was the Prairie Research Unit in Prairie, MS. The Prairie Research Unit is part of the Mississippi Agricultural and Forestry Experiment Station administered by Mississippi State University. The site is located in the blackland prairie soil type region of Mississippi in Monroe County, MS. Monroe County and surrounding counties are some of the top counties in Mississippi for annual beef cattle inventory per the Mississippi Agricultural Statistics Service. All experiments within this project (protocol 14-050) were approved via the Institutional Animal Care and Use Committee (IACUC) at Mississippi State University. The IACUC approval process requires evidence of appropriate sample size determination and planned data collection and statistical methods. Only Mississippi Agricultural and Forestry Experiment Station personnel were used in implementation of project protocols. Data remained on site at the Prairie Research Unit and were analyzed at that location. Samples for laboratory analysis were prepared for shipment including proper labelling at the Prairie Research Unit and shipped directly to a contracted laboratory for analysis. Laboratory results were reported directly from the laboratory to the Prairie Research Unit. Project methods and results were published via referred academic journals which scrutinized methods and results before approval for publication.

Findings

Warm-season forages
Warm-season grazing (Objective 1). Mean forage nutritive values on a dry matter basis for grazed warm-season forage were: bermudagrass (8.8% CP, 43.4% ADF, 67.3% aNDF, 58.7% TDN, and 77 RFV), indiangrass (6.7% CP, 39.6% ADF, 68.3% aNDF, 58.2% TDN, and 79 RFV) and mixed native warm-season grass (big bluestem, little bluestem, and indiangrass) (7.3% CP, 40.5% ADF, 69.5% aNDF, 58.1% TDN, and 77 RFV). A forage treatment x day x year effect existed (P < 0.01) for all of these nutritive values. There was no effect (P = 0.47) of forage treatment on calf average daily gain over the 56-day grazing period (bermudagrass 0.4 ± 0.1 kg/day; indiangrass 0.5 ± 0.1 kg/day; mixed native warm-season grass 0.5 ± 0.1 kg/day).

Warm-season stocking rate (Objective 2). Forage nutritive values expressed on a dry matter basis were not different between the high (1.5 acres/calf) and low (2.0 acres/calf) (mean initial day 0 calf body weight = 293.5 kg) stocking rates, respectively, for crude protein (7.0 ± 0.2% vs 6.7 ± 0.2%; P = 0.27), acid detergent fiber (41.0 ± 0.6 vs 41.4 ± 0.6; P = 0.64), acid indigestible neutral detergent fiber (69.9 ± 0.5 vs 68.7 ± 0.5; P = 0.09), or relative feed value (76.0 ± 1.0 vs 76.9 ± 1.0; P = 0.53). However, there was a year effect (P < 0.01) and forage treatment x day effect (P < 0.01) for total digestible nutrients. At the low stocking rate, total digestible nutrients decreased from day 0 to day 28 (P = 0.02) and again decreased from day 28 to day 56 (P = 0.02). However, at the high stocking rate, total digestible nutrients decreased (P < 0.01) from day 0 to day 28 but remained steady until day 56 (P = 0.21). This suggests that the additional grazing pressure of the high stocking rate helped mitigate the total digestible nutrients decrease observed in the low stocking rate. This is possible with the additional defoliation by the grazing animals helping to maintain a less mature stage of plant growth. Thus, there may be some nutritive value advantages to grazing cattle by utilizing the high stocking rate relative to the low stocking rate.

There was no net advantage for calf body weight average daily gain for either stocking rate over the other stocking rate. Yet there was a forage treatment x day interaction (P < 0.01) with average daily gains listed in order from greatest to least: low stocking rate day 28 to 56 (1.20 ± 0,.08 kg/day), high stocking rate day 0 to 28 (0.89 ± 0,.08 kg/day), high stocking rate day 28 to 56 (0.44 ± 0,.08 kg/day), and low stocking rate day 0 to 28 (0.30 ± 0,.08 kg/day).

Warm-season conserved forage intake (Objective 3). Mean forage nutritive values on a dry matter basis for ensiled forage were: bermudagrass (11.2% CP, 36.4% ADF, 69.2% aNDF, 56.3% TDN, and 82 RFV) and mixed native warm-season grass (9.7% CP, 40.2% ADF, 70.8% aNDF, 56.0% TDN, and 76 RFV). There was a forage species × year effect ($P = 0.02$) for mean daily intake of ensiled forage by steers over 35-day periods in each of 2 years. On an as-fed basis, steers offered ad libitum ensiled forage consumed more ($P < 0.01$) amounts of bermudagrass (7.95 ± 0.13 kg/day) than mixed native warm-season grass (6.92 ± 0.13 kg/day) in 2015. In 2016 steers consumed more ($P < 0.01$) bermudagrass (9.70 ± 0.13 kg/day) than mixed native warm-season grass (8.06 ± 0.13 kg/day) ensiled forage. However, there was no difference ($P = 0.56$) in as-fed intake of bermudagrass in 2015 relative to mixed native warm-season grass in 2016.

Cool-season forages

Herbage Mass. There was a date x year interaction ($P < 0.01$) for herbage mass. Herbage mass was greatest at day 0 in 2015 (5,480 ± 233.5 kg DM/ha) and least at day 56 in 2015 (2,723 ± 233.5 kg DM/ha; $P < 0.01$). Herbage mass decreased every 28 days in 2015, was not different ($P = 0.82$) between day 0 and day 28 in 2016, and then decreased ($P < 0.01$) from day 28 to day 56 in 2016. The grazing season ending herbage mass was greater ($P < 0.01$) in 2016 than in 2015. There was also a forage species x date interaction ($P < 0.01$) for herbage mass. At day 0, WHT herbage mass (6,694 ± 264.6 kg DM/ha) was greatest, ARG (4,746 ± 264.6 kg DM/ha) intermediate, and VWR (3,843 ± 264.6 kg DM/ha) least among the forage species studied. By day 28, herbage mass was not different ($P = 0.21$) between VWR and ARG, and both were less ($P < 0.01$) than WHT. Later at day 56, herbage mass did not differ ($P = 0.36$) amongst the three forage species. Herbage mass of each forage species decreased progressively every 28 days. These herbage mass results are not surprising given that WHT is known for its earlier cool-season growth profile relative to ARG. Likewise, it is intuitive than both WHT and ARG, as annual grasses, produced more herbage mass in April compared with VWR, a perennial grass, but by start of June herbage mass was decreased and comparable amongst all three forages. Throughout the grazing season, there was adequate herbage mass to support ad libitum grazing dry matter intake without restriction. Although plant persistence as pasture over time was not assessed in the present short-term study, it warrants further attention.

Nutritive Value. Year × date interactions ($P < 0.01$) were detected for TDN, aNDF, and ADF concentrations as well as for RFV. The TDN concentrations were greatest at day 0 and day 28 in 2015, next greatest at day 0 in 2016, followed by day 56 in 2015, and least at day 28 and day 56 in 2016. The aNDF concentrations were greatest at day 56 in both years as would be reasonable to expect as fiber concentrations increased with advancing forage maturity. The second greatest aNDF concentration occurred at day 28 in 2016, followed by lesser concentrations at day 0 and day 28 in 2015, and the least concentration at day 0 in 2016. Again, earlier season aNDF values are explained by earlier forage maturity stages in which fiber is expected to comprise less of the forage leaves. Forage ADF concentrations followed a somewhat similar pattern to aNDF, with the greatest ADF concentration measured at day 56 in 2015 and the next greatest concentration observed at day 56 in 2016. Intermediate ADF concentrations were documented at day 0 and day 28 in 2015 and day 0 in 2016. The least ADF concentration was noted at d 0 of 2016. The greatest RFV, 137.4, was observed at day 0 in 2016. The next greatest RFV occurred at day 0 and day 28 in 2015 and day 28 in 2016. The least RFV were in forage samples harvested at day 56 in both years. The RFV pattern of decreasing throughout the growing season was expected from positive correlations of advancing forage maturity increased plant fiber concentrations. There were no differences among the forage species for TDN ($P = 0.87$), aNDF ($P = 0.83$), or ADF ($P = 0.17$) concentrations.

There was a forage species x date interaction ($P = 0.03$) for relative feed value (RFV). Relative feed value ranks forages according to predicted digestible dry matter intake (DMI), which is DMI multiplied by the percentage of digestible dry matter (Hackmann et al., 2008). At day 0, ARG RFV concentration (133.8 ± 5.4) was greater ($P < 0.05$) than that of VWR (111.2 ± 5.4) or WHT (117.7 ± 5.4). At day 28 ($P = 0.08$) and again at d 56 (P = 0.56), RFV was not different among the 3 forage species. As expected, the RFV of each forage species decreased (P = 0.02) progressively every 28 days with advancing forage maturity, with the exception that RFV of VWR was comparable between day 0 and day 28 (P = 0.46). Given that a reference RFV = 100 represents the nutritive value of full-bloom alfalfa (*Medicago sativa* L.), assuming 41% ADF and 53% NDF (Karayilanli and Ayhan, 2016), the RFV observed at day 0 indicate forage nutritive value expressed as RFV that was greater than full-bloom alfalfa for the 3 forage species studied here. By day 28, RFV was equivalent to 100 for ARG, WHT, and VRW, but RFV decreased dramatically in all 3 forage species by day 56 to levels much less than the full-bloom alfalfa reference RFV.

A grazing year × forage species interaction was significant (P = 0.02) for CP). No crude protein (CP) concentration differences (P = 0.12) were observed among forage species in 2015. However, in 2016, CP concentration of VWR was greater (P = 0.01) than that of WHT. The CP concentration of VWR in 2016 was also greater than the CP concentrations of VWR and ARG in 2015. There was also a date effect (P < 0.01) for CP with concentrations decreasing as the grazing season progressed from 11.3 ± 0.4% at day 0 down to 8.5 ± 0.4% at day 28 and down more to 7.5 ± 0.4% at day 56. Decreasing CP concentrations with advancing forage maturity were anticipated and have been observed by others in cool-season annual and perennial forages.

The literature and present results suggest that VWR pastures are competitive with widely used cool-season grass alternatives in terms of nutritive value. As expected, VWR may be most nutrient dense earlier in the grazing season; and, it is reasonable to postulate that greater grazing animal growth rates could be supported during periods of greater forage nutritive value.

Average Daily Gain (ADG). Steer ADG was greater on ARG (1.40 ± 0.05 kg/steer/day) than on WHT (1.20 ± 0.05 kg/steer/day) (P < 0.01) or VWR (1.26 ± 0.05 kg/steer/day) (P = 0.03), and ADG between WHT and VWR were comparable (P = 0.38). In addition, there was a year effect (P < 0.01) for ADG. Steer ADG was greater in 2016 (1.51 ± 0.04 kg/steer/day) than in 2015 (1.07 ± 0.04 kg/steer/day). Whereas, annual ryegrass is the predominant cool-season annual pasture grass in North Mississippi, tall fescue is the predominant cool-season perennial grass in this area. This suggests that ARG, WHT, and VWR are all reasonable alternatives to tall fescue for supporting good stocker calf grazing growth performance in North Mississippi. With the observation in the present study of a year effect for ADG, it is suggested that environmental conditions influence animal growth performance on cool-season pastures to the extent that ADG rankings may change from one year to another.

In the present study, because herbage mass was not limiting for DMI, it is reasonable that subtle nutritive value advantages of ARG explain at least a proportion of the greater ADG on this forage species relative to VWR and WHT. The superior relative feed value (RFV) at day 0 for ARG over VWR and WHT was the observable nutritive value advantage of ARG. However, it is plausible that there were DMI differences amongst forage species that contributed to this steer growth performance difference; yet this remains speculation only because forage DMI was not quantified in this study.

Forage intake (Objective 4). Mean forage nutritive values on a dry matter basis for ensiled forage were: ARG (10.9% CP, 30.5% ADF, 48.3% aNDF, 63.5% TDN, and 126 RFV) and VWR (11.3% CP, 30.7% ADF, 53.7% aNDF, 62.0% TDN, and 113 RFV). There was a forage species × year effect (P < 0.0001) for mean daily intake of ensiled forage by steers (initial BW 269.5 ± 6.4 kg) over 35-day periods in each of 2 years. On an as-fed basis, steers offered ad libitum ensiled forage consumed comparable (P = 0.90) amounts of ARG (8.79 ± 0.15 kg/day) and VWR (8.81 ± 0.15 kg/day) in 2015. However, in 2016 steers consumed more (P < 0.0001) VWR (8.29 ± 0.15 kg/day) than ARG (6.81 ± 0.15 kg/day) ensiled forage despite no advantage in aNDF concentrations to justify this result. As-fed intake of VWR was less (P = 0.02) in 2016 than 2015, and also intake of ARG was less (P < 0.0001) in 2016 than 2015. Interestingly, forage nutritive values did not explain the forage intake differences observed.

Overall, the findings supported the goals of the project by validating that selected native warm- and cool-season grasses supported comparable stocker calf intake and growth performance relative to selected improved forages (i.e., bermudagrass and wheat). One exception was that annual ryegrass outperformed Virginia wildrye in terms of weaned calf average daily gain. Forage nutritive values for native grasses were also comparable to their improved grass counterparts.

Conclusions and Recommendations

Forage nutritive values varied by date and year for bermudagrass, indiangrass, and mixed native warm-season grass (big bluestem, little bluestem, and indiangrass) pastures. There were few differences among annual ryegrass, wheat, and Virginia wildrye for forage nutritive values with the exception of a crude protein advantage for Virginia wildrye over wheat in one year and superior relative feed value (RFV) for annual ryegrass in early April. Nutritive values generally decreased as the grazing season progressed towards the end of spring and summer seasons with advancing forage maturity. Overall grazing calf growth rates did not did among the warm-season forage treatments. There was also no net advantage for calf body weight average daily gain on the mixed native warm-season grass pastures between the stocking rates observed. Stocker calf average daily gain was greatest on annual ryegrass during spring grazing among these three cool-season grasses. All forages tested were demonstrated to be viable sources of conserved forage that could be stored and fed in a season outside of the production season. This shows the potential for use in drought mitigation for livestock feeding in both warm- and cool-season production scenarios.

Given the varying seasonal growth profiles of these forages, it would be useful for future research to assess these forages over a greater portion of the year including autumn and winter periods to gain a more comprehensive understanding of their potential contributions to grazing systems in the region. Questions remain, given the relatively expensive seed cost of native grasses, as to the economics of replacing improved forages with this native grass species. Additionally, plant productivity and persistence over time need to be assessed to determine long-term effectiveness of using native grasses in pasture settings. The current project focused on native grasses for drought mitigation, however, with extreme wet conditions common in the Southeast U.S., native grass productivity and survival under those excessively wet conditions likewise warrants study.

Technology Review Criteria

The technology reviewed in this project was native grass species for use in cattle grazing and stored forage confinement feeding scenarios. Specifically, native grass species reviewed were:

- Big bluestem (warm-season native grass)
- Little bluestem (warm-season native grass)
- Indiangrass (warm-season native grass)
- Virginia wildrye (cool-season native grass)

This project established a previously non-existent direct comparison of Virginia wildrye versus annual ryegrass and wheat for forage nutritive value and calf growth performance. It also provided warm-season grass native comparisons (indiangrass and a mix of big bluestem, little bluestem and indiangrass) to bermudagrass in a geographical area (blackland prairie of Northeast MS) for which there was previously a dearth of information. These grasses are commercially available and can be immediately used in cattle production systems. Therefore, use guidance is warranted to achieve optimal outcomes.

These native grass forage technologies should be monitored for the following:

- Forage establishment cost (including seeding rate and cost; consider annual versus perennial forage stand lives)
    - A Mississippi State University Extension publication on native grass establishment and maintenance costs is online at http://extension.msstate.edu/publications/publications/native-warm-season-grasses-forage-ms-establishment-and-maintenance-costs
- Forage establishment agronomic success risk (note conditions that may not be conducive to obtaining a successful forage stand establishment; one managed in the current study was protecting from grazing defoliation and treading until well established).
    - A Mississippi State University Extension publication on native grass establishment issues is online at http://extension.msstate.edu/sites/default/files/publications//P2868_web.pdf
    - A Mississippi State University Extension publication on native grass weed control is online at http://extension.msstate.edu/sites/default/files/publications/publications/p2880.pdf
    - Publication authors are contacts for further information on successful technology implementation.
- Forage nutritive value throughout the grazing season and with varying soil amendments (primarily consider crude protein and total digestible nutrients for using forages as inputs into livestock nutrition programs)
- Forage herbage mass (herbage availability) with varying stocking rates, throughout the growing season, and from year to year (keep accurate animal stocking records including animal numbers and animal weights)
    - A Mississippi State University Extension publication on native grass grazing management is online at https://extension.msstate.edu/sites/default/files/publications/publications/P2843.pdf
    - A Mississippi Agricultural and Forestry Experiment Station publication on forage herbage mass yield including Virginia wildrye is online at https://extension.msstate.edu/sites/default/files/publications/variety-trials/ib0530-perennial-cool-season-forage-crop-%20variety-trials-2017.pdf

Appendices

Project Publications

Referred Journal Article:

Parish, J. A. 2018. Comparison of Virginia wild rye, annual ryegrass, and wheat for weaned beef steer grazing and confinement feeding. Prof. Anim. Sci. 34(4):356-363.

Referred Journal Abstract:

Parish, J. A., T. F. Best, and C. O. Stewart. 2016. Virginia wildrye as an alternative to annual ryegrass and wheat for grazing stocker beef steers. J. Anim. Sci. 94(E-Suppl. 3). (Abstr.).
Presented at American Society of Animal Science Southern Section Annual Meeting, American Society of Animal Science Southern Section, San Antonio, TX on February 9, 2016.

Literature Cited in Methods

Monroe, A. P. 2017. Economic and conservation implications of converting exotic forages to native warm-season grass. Global Ecology and Conservation. 11:23-32.

The Professional Animal Scientist 34:356–363
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Comparison of Virginia wildrye, annual ryegrass, and wheat for weaned beef steers grazing and confinement feeding

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ABSTRACT

Virginia wildrye (*Elymus virginicus* L.; VWR) was compared with Marshall annual ryegrass (*Lolium multiflorum*; ARG) and EK102 wheat (*Triticum aestivum*; WHT) as pasture and with ARG for confinement feeding. Replicated (n = 3) 2.17-ha pastures were continuously stocked with 4 British crossbred steers (initial BW = 233 ± 28.5 kg) per pasture during spring in 2 yr to evaluate ADG and forage nutritive value. Forage TDN ($P = 0.87$), NDF treated with amylase and sodium sulfite ($P = 0.83$), and ADF ($P = 0.17$) were comparable among species. No CP concentration differences ($P = 0.12$) were observed in 2015; however, CP concentration of VWR (10.1 ± 0.5) was greater ($P = 0.01$) than that of WHT (8.7 ± 0.5) in 2016. At d 0, ARG relative feed value concentration (133.8 ± 5.4) was greater ($P < 0.05$) than that of VWR (111.2 ± 5.4) or WHT (117.7 ± 5.4). At d 28 ($P = 0.08$) and d 56 ($P = 0.56$), relative feed value was not different among species. Steer ADG was greater on ARG (1.40 ± 0.05 kg/steer per day) than on WHT (1.20 ± 0.05 kg/steer per day; $P < 0.01$) or VWR (1.26 ± 0.05 kg/steer per day; $P = 0.03$). Penned steers had comparable ($P = 0.90$) daily DMI of ensiled ARG (7.99 ± 0.14 kg/d) and VWR (7.88 ± 0.14 kg/d) in 2015 but more ($P < 0.0001$) daily DMI of VWR (7.42 ± 0.14 kg/d) than of ARG (6.19 ± 0.14 kg/d) in 2016. Further research is needed to explore forage persistence and economics of VWR for grazing.

Key words: wildrye, annual ryegrass, wheat, native grass, grazing

INTRODUCTION

The perennial grass Virginia wildrye (*Elymus virginicus* L.; **VWR**) is a cool-season forage that is not widely used in forage systems for beef cattle production in the southeastern United States. The short-lived, perennial nature of VWR, often 5 or fewer growing seasons, and lack of known concerns regarding grazing-livestock toxicity may make it a reasonable alternative to more commonly adopted cool-season forages in the region. In comparison, tall fescue [*Lolium arundinaceum* (Schreb.)], a perennial grass occupying much of the cool-season pasture in the region, is a causative agent in fescue toxicosis when infected with the wild-type endophyte (*Neotyphodium coenophialum*). Annual grasses such as annual ryegrass (*Lolium multiflorum*; **ARG**) and wheat (*Triticum aestivum*; **WHT**) can be used to produce highly productive grazing livestock but must be established on an annual basis; instead, cool-season, perennial grasses may improve returns to stocker cattle producers via decreased annual establishment cost (Islam et al., 2011).

There is interest in use of VWR, considered a native forage species, from the standpoint of developing wildlife habitat in pasture systems. Nielsen and Kelly (2016) recognized the long-term ecosystem services of VWR as a perennial forage species to wildlife habitat restoration in riparian areas by providing ground cover throughout the year without the need for annual renovation. Sanderson et al. (2004a) noted that increased interest in native plant species for conservation and production is due to new federal policies. Rushing and Baldwin (2013) suggested a need in northeast Mississippi, the locale of the present investigation, for a native, cool-season grass for restoring and reclaiming grasslands while simultaneously providing forage with acceptable nutritive value for livestock. Virginia wildrye is reported to have CP values of 23, 19, and 7% in the vegetative, flower/boot, and fruit/head stages, respectively, as well as 80, 74, and 60% IVDMD values for these same stages, respectively (Bosworth et al., 1985). A comparison of VWR to other cool-season grasses in the northeastern United States including orchardgrass (*Dactylis glomerata* L.) showed comparable nutritive values (Sanderson et al., 2004b). In the southeastern United States, *Elymus* species were similar to domesticated, nonnative species including tall fescue for forage nutritive value attributes (Rushing and Baldwin, 2013). The objectives of these experiments were to compare steer growth performance and forage nutritive value of 3 cool-season forage grasses (VWR, ARG, and WHT) and to assess steer intake of VWR versus ARG as ensiled forage. The authors hypothesized that similar animal growth performance would be measured among the 3 forage species.

The author declares no conflict of interest.
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MATERIALS AND METHODS

Exp. 1: Grazing VWR vs. ARG or WHT Pastures

Pasture Establishment and Management. Three cool-season forage grasses (ARG, WHT, and VWR) were compared for forage nutritive value and steer growth performance for 2 yr at the North Mississippi Research and Extension Center Prairie Research Unit (**PRU**) at Prairie, Mississippi (latitude 33.7891°N; longitude 88.6585°W; elevation 100 m). This grazing experiment was a randomized complete block design. There were 9 total pastures: 3 pasture treatments with 3 replications each randomly arranged in 3 blocks. Soil type was Houston clay. The 2.17-ha pastures were clipped to 3-cm stubble height in mid-August each year. After volunteer grass seedlings emerged in late August, an application of glyphosate (1.5 L/ha of 41% vol/vol) was applied to eradicate the existing pasture species. Glyphosate was not applied to the VWR pastures after establishment. On September 17 to 19, 2014, and September 16 to 18, 2015, the VWR (2014 planting only), ARG, and WHT seed were no-till drilled at seeding rates of 16.8, 33.6, and 112.1 kg/ha, respectively. The ARG and WHT pastures were planted to the same forage species in both years. Nitrogen (27.2 kg of N/ha) was applied as ammonium nitrate 2 wk after seedling emergence from the soil in October each year. Soil samples collected at the research site to a 15.2-cm depth were submitted to the Mississippi State University Extension Service Soil Testing Laboratory (Mississippi State, MS), and these test results indicated that lime, P, and K applications were not necessary.

Cattle and Grazing Management. The cattle in this experiment were managed under protocol 14–050 approved by the Mississippi State University Institutional Animal Care and Use Committee. Weaned British crossbred steers (mean initial BW ± SE = 276 ± 10.4 kg) less than 1 yr of age were acquired from the resident Mississippi Agricultural and Forestry Experiment Station herd at PRU. Four steers per paddock were used each grazing season. Before each grazing season, calves were vaccinated for protection against respiratory disease complex with Pyramid 10 (Boehringer Ingelheim Vetmedica Inc., St. Joseph, MO), clostridial diseases with Vision 7 (Intervet Inc., Millsboro, DE), and *Mannheimia* diseases with Presponse SQ (Fort Dodge Laboratories Inc., Fort Dodge, IA). Cattle were also treated for internal and external parasites with EPRINEX pour-on (Merial, Duluth, GA) at a dosage rate according to the product label and applied an XP 820 insecticide fly tag (Y-Tex Corporation, Cody, WY) in one ear per steer at grazing initiation.

The cattle were grazed together on mixed sward cool-season grass pasture for 14 d before being stratified by BW and breed composition and then randomly assigned to experimental paddocks at the beginning of each grazing season. These steers remained on their original assigned experimental paddocks for the duration of the grazing season. In each paddock, cattle were supplied with access to fresh water and free-choice mineral supplement (Purina Wind & Rain Storm Fescue Hi Mag 5 CO AU2800 Medicated; Purina Animal Nutrition LLC, Shoreview, MN) containing 3.09 g/kg of chlortetracycline and not less than 13.5% Ca, 5.0% P, 18.0% salt (NaCl), 10.0% Mg, 0.1% K, 4,800 mg/kg of Mn, 4,800 mg/kg of Zn, 1,600 mg/kg of Cu, 80 mg/kg of I, 16 mg/kg of Co, and 27 mg/kg of Se. The mineral supplement was labeled to contain not less than 661,386.8 IU of vitamin A/kg, 66,138.7 IU of vitamin D/kg, and 661.4 IU of vitamin E/kg.

Spring grazing seasons were 56 d each. Grazing periods for the year were as follows: April 8 to June 3, 2015, and April 6 to June 1, 2016, with the calves grazing the pastures for the entire duration of these grazing periods. Grazing initiation was based on availability of at least 3,500 kg/ha forage mass in all paddocks. Continuous stocking management was used. Paddocks were restocked with new animals at the beginning of each grazing season.

Pasture Data Collection. Paddocks were measured every 28 d beginning d 0 through the end of each grazing season to monitor herbage mass using a double sampling technique (Burns et al., 1989). The sward height was measured using a falling plate disk meter with 50 contacts per paddock. In each paddock, the first disk meter contact site was selected by walking a randomly selected number of steps into the pasture from the gate. Thereafter, a fixed number of steps, estimated to cover 5 diagonal transects in a zigzag pattern in each paddock, were used to determine the rest of the contact sites so as to spatially cover the entire paddock. After taking disk measurements in each paddock, herbage from three 0.25-m^2 quadrats was harvested at 2.5 cm above the soil surface at sites selected to approximate the shortest, mean, and tallest disk meter readings recorded in the paddock to calibrate the indirect estimates (disk meter readings) with direct estimates (harvested herbage samples). The quadrat cuts from each paddock were weighed fresh and then pooled within grazing paddock within pasture replicate. From each pooled sample, a 1-kg subsample was taken, dried in a forced-air oven at 60°C for 72 h, and then weighed to determine DM concentration. A regression equation was developed for each sampling date, with direct measurements (DM weight of clipped samples) as the dependent variable and indirect estimates (disk readings) as the independent variable. Herbage mass was then estimated with the resulting regression equation using the mean of the 50 disk readings per paddock. Season average herbage mass was calculated as the mean of all herbage mass estimates taken within each season.

Subsamples of the pooled herbage samples from d 0, 28, and 56 of the grazing period were frozen at −20°C, lyophilized, ground through a 1-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ), and shipped to a commercial laboratory (Dairy One Forage Lab, Ithaca, NY) to be analyzed for nutritive value including DM, TDN (Cherney et al., 1997), NDF treated with amylase and sodium sulfite (**aNDF**), ADF (Van Soest et al., 1991), and total N (AOAC, 1990). Crude protein concentration was determined by multiplying total N concentration by 6.25. Relative feed value was calculated from ADF and NDF using Dairy One Forage Lab equations with a relative feed value (**RFV**) of 100 considered the mean score and representing an alfalfa (*Medicago sativa* L.) hay containing 41% ADF and 53% NDF on a DM basis.

Steer Data Collection. Steer BW were collected at the onset of each grazing season and at 28-d intervals thereafter. Initial and final unshrunk steer BW were collected by averaging weights obtained on 2 consecutive days. Steer days for each pasture were calculated as the sum of the days each calf spent grazing the pasture during a given grazing season. Steer ADG was computed by dividing mean BW gain in a particular paddock by the number of days in the grazing season. Mean stocking rate was computed by dividing steer days by the duration of the grazing season in days and then multiplying by the mean steer BW. Mean herbage allowance was calculated as the quotient of mean herbage mass divided by mean stocking rate. Body weight gain per hectare was calculated as the number of steer days multiplied by steer ADG. For 28-d periods, the previously described calculations were used, but instead of considering the entire grazing season, only data from the particular 28-d period of interest were used.

Exp. 2: Confinement Feeding of VWR or ARG

Fields of ARG and VWR were established at PRU in September 2014 (and again in September 2015 for the second year of ARG production) for the purpose of ensiled forage production. Fields were precision drilled and fertilized as described for Exp. 1 but were separate from the pastures used in Exp. 1. At harvest in May of 2015 and 2016, moisture of cut forage was monitored using a moisture meter (Windrow Hay Moisture Tester; AgraTronix LLC, Streetsboro, OH) to target baling forage at approximately 50% moisture. Forage was cut using a rotary disk mower (GMD 310; Kuhn North America Inc., Brodhead, WI), raked, and baled into 1.5-m × 1.5-m round bale packages (John Deere 557 Round Baler; John Deere, Moline, IL). These bales were immediately individually encased with 21 wraps per bale of a white plastic (Tytan silage wrap; Tytan International LLC, Lenexa, KS) to create an anaerobic environment for ensiling and then stored either outdoors or in open-air barns until feeding. Forage nutritive value was determined by the same methods as described for Exp. 1.

Forage intake and feeding behavior were monitored using a GrowSafe Model 6000 feed intake and behavior monitoring system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada) at PRU. Twenty-four weaned British crossbred steers (initial BW = 269 ± 6.4 kg) less than 1 yr of age from the resident PRU herd were allocated to this experiment each year. Steers were stratified by BW and breed composition and then randomly assigned to pens at the beginning of each year of this experiment. Vaccination and animal health treatments of steers were the same as in Exp. 1. There were 3 steers per pen across 8 pens, and each pen contained 2 GrowSafe feed nodes in which forage was offered to the steers ad libitum. Pens were 7.6 m × 22.6 m in area including an area with a concrete floor under a shed providing shade at all times where the GrowSafe feed nodes were contained and an adjoining dirt-floored drylot area outside the shed. Overhead fans were used to circulate air in the shed. A 14-d acclimation period was used to acclimate the steers to consuming forage in the GrowSafe feeding system before the start of the experiment. Steers were weighed unshrunk on 2 consecutive days at the beginning and end of the experiment and initial and final weights averaged, respectively. In 4 of the GrowSafe pens, steers were offered VWR conserved as ensiled forage; in the other 4 GrowSafe pens steers were offered ARG conserved as ensiled forage. At feeding, plastic wrap and twine were removed from individual bales, and bales were chopped in a bale processor (BPX9000, Vermeer Corporation, Pella, IA) for ease of feeding. The ensiled forage was then delivered to the GrowSafe bunks by hand feeding at least once daily and more frequently as needed to ensure ad libitum forage access during the experiment. Bunks were cleaned approximately once per week or as needed to remove feed refusals or forage that had packed on the floor of the bunks and immediately refilled with freshly processed ensiled forage. All steers were offered ad libitum access to a loose mineral supplement contained in a separate feed trough in each pen. The mineral supplement (Purina Wind & Rain Storm All Season 7.5CP AU5600 Altosid Medicated; Purina Animal Nutrition LLC) was labeled to contain 6.17 g/kg of chlortetracycline, 0.14 g/kg of S-methoprene, 13.5% Ca, 7.5% P, 18.0% salt (NaCl), 1.0% Mg, 1.0% K, 3,600 mg/kg of Mn, 3,600 mg/kg of Zn, 1,200 mg/kg of Cu, 60 mg/kg of I, 12 mg/kg of Co, and 27 mg/kg of Se, 661,386.8 IU of vitamin A/kg, 66,138.7 IU of vitamin D/kg, and 661.4 IU of vitamin E/kg. Steers were supplied with fresh water at all times via JUG Model 202 water troughs (Bakko Industries Inc., Glenwood, MN) in each pen.

Statistical Analysis

The MIXED procedure of SAS (SAS Institute Inc., Cary, NC) was used to analyze continuous data from the experiment, whereas PROC GLIMMIX was used to analyze data expressed as percentages including forage nutritive value traits. A randomized complete block experimental design was used with paddock or pen as the experimental unit. Main effects were forage species, grazing period, and grazing year. Grazing period and grazing year were repeated measurements. The model included main effects and their interactions. Forage species effects were tested using paddock or pen within forage species as the error term. Period effects and period × forage species were tested using period × paddock or pen within forage species as the error term. Because block was not a significant source of varia-

Table 1. Mean forage herbage mass, TDN, aNDF, ADF, and relative feed value on a DM basis as affected by date within the grazing year[1]

	2015			2016				*P*-value
Item	d 0	d 28	d 56	d 0	d 28	d 56	SEM	Year × date
Herbage mass, kg of DM/ha	5,480[a]	3,738[c]	2,723[d]	4,709[b]	4,765[b]	3,499[c]	234	<0.01
TDN, %	63.7[a]	63.6[a]	60.3[c]	62.0[b]	57.6[d]	56.6[d]	0.4	<0.01
aNDF,[2] %	54.1[b]	55.7[b]	68.5[a]	46.7[c]	57.6[b]	67.0[a]	1.6	<0.01
ADF, %	36.9[c]	38.6[c]	47.1[a]	27.3[d]	38.2[c]	42.9[b]	1.0	<0.01
Relative feed value	104.3[b]	100.4[b]	71.1[c]	137.4[a]	96.3[b]	77.2[c]	4.4	<0.01

[a–d]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Year: feeding years were April 8 to June 3, 2015, and April 6 to June 1, 2016. Date: d 0 = April 8, 2015, and April 6, 2016; d 28 = May 6, 2015, and May 4, 2016; d 56 = June 3, 2015, and June 1, 2016.

[2]aNDF = NDF treated with amylase and sodium sulfite.

tion, and there were no significant interactions involving block, means were pooled within treatment across blocks. Means were separated at $P < 0.05$ using the PDIFF function of SAS using the default *t*-test pairwise differences.

RESULTS AND DISCUSSION

Exp. 1

Herbage Mass Discussion. There was a date × year interaction ($P < 0.01$) for herbage mass (Table 1). Herbage mass was greatest at d 0 in 2015 (5,480 ± 233.5 kg of DM/ha) and least at d 56 in 2015 (2,723 ± 233.5 kg of DM/ha; $P < 0.01$). Herbage mass decreased every 28 d in 2015, was not different ($P = 0.82$) between d 0 and 28 in 2016, and then decreased ($P < 0.01$) from d 28 to 56 in 2016. The grazing season ending herbage mass was greater ($P < 0.01$) in 2016 than in 2015. There was also a forage species × date interaction ($P < 0.01$) for herbage mass (Table 2). At d 0, WHT herbage mass (6,694 ± 264.6 kg of DM/ha) was greatest, ARG (4,746 ± 264.6 kg of DM/ha) intermediate, and VWR (3,843 ± 264.6 kg of DM/ha) least among the forage species studied. By d 28, herbage mass was not different ($P = 0.21$) between VWR and ARG, and both were less ($P < 0.01$) than WHT. Later at d 56, herbage mass did not differ ($P = 0.36$) among the 3 forage species. Herbage mass of each forage species decreased progressively every 28 d. These herbage mass results are not surprising given that WHT is known for its earlier cool-season growth profile relative to ARG. Likewise, it is intuitive that both WHT and ARG, as annual grasses, produced more herbage mass in April compared with VWR, a perennial grass, but by the start of June, herbage mass was decreased and comparable among all 3 forages. Throughout the grazing season, there was adequate herbage mass to support ad libitum grazing DMI. Redmon et al. (1995) defined the forage allowance at which or less than which it becomes limiting to calf growth as 20 to 24 kg of DM/100 kg of BW for cool-season grasses. This allowance was exceeded throughout the current experiment. Although plant persistence as pasture over time was not assessed in the present short-term experiment, it warrants further attention. There is published evidence that VWR is less persistent than orchardgrass (*Dactylis glomerata* L.), for example, as reported by Sanderson et al. (2004a).

Nutritive Value. Year × date interactions ($P < 0.01$) were detected for TDN, aNDF, and ADF concentrations as well as for RFV (Table 1). The TDN concentrations were greatest at d 0 and 28 in 2015, next greatest at d 0 in 2016, followed by d 56 in 2015, and least at d 28 and 56 in 2016. The aNDF concentrations were greatest at d 56 in both years as would be reasonable to expect because fiber concentrations increased with advancing forage maturity. The second greatest aNDF concentration occurred at d 28 in 2016, followed by lesser concentrations at d 0 and 28 in 2015, and the least concentration at d 0 in 2016. Again, earlier season aNDF values are explained by earlier forage maturity stages in which fiber is expected to comprose less of the forage leaves. Forage ADF concentrations followed a somewhat similar pattern to aNDF, with the greatest ADF concentration measured at d 56 in 2015 and the next greatest concentration observed at d 56 in 2016. Intermediate ADF concentrations were documented at d 0 and 28 in 2015 and d 0 in 2016. The least ADF concentration was noted at d 0 of 2016. The greatest RFV, 137.4, was observed at d 0 in 2016. The next greatest RFV occurred at d 0 and 28 in 2015 and d 28 in 2016. The least RFV were in forage samples harvested at d 56 in both years. The RFV pattern of decreasing throughout the growing season was expected because as forage maturity advanced, plant fiber concentrations increased. There were no differences among the forage species for TDN ($P = 0.87$), aNDF ($P = 0.83$), or ADF ($P = 0.17$) concentrations.

There was a forage species × date interaction ($P = 0.03$) for RFV (Table 2). Relative feed value ranks forages according to predicted digestible DMI, which is DMI multiplied by the percentage of digestible DM (Hackmann et

Table 2. Mean forage herbage mass and relative feed value on a DM basis as affected by forage species and date within the grazing year[1]

Item	d 0			d 28			d 56			SEM	*P*-value
	VWR	ARG	WHT	VWR	ARG	WHT	VWR	ARG	WHT		Date × forage species
Herbage mass, kg of DM/ha	3,843[cd]	4,746[b]	6,694[a]	3,635[cde]	4,025[c]	5,094[b]	2,941[f]	3,225[def]	3,168[ef]	265	<0.01
Relative feed value	111.2[bc]	133.8[a]	117.7[b]	105.5[bcd]	91.7[de]	98.0[cd]	77.2[ef]	72.7[f]	72.7[f]	5.4	0.03

[a–f]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Date: d 0 = April 8, 2015, and April 6, 2016; d 28 = May 6, 2015, and May 4, 2016; d 56 = was June 3, 2015, and June 1, 2016. Forage species: VWR = Virginia wildrye; ARG = Marshall annual ryegrass; WHT = EK102 wheat.

al., 2008). At d 0, ARG RFV concentration (133.8 ± 5.4) was greater ($P < 0.05$) than that of VWR (111.2 ± 5.4) or WHT (117.7 ± 5.4). At d 28 ($P = 0.08$) and again at d 56 ($P = 0.56$), RFV was not different among the 3 forage species. As expected, the RFV of each forage species decreased ($P = 0.02$) progressively every 28 d with advancing forage maturity, with the exception that RFV of VWR was comparable between d 0 and 28 ($P = 0.46$). Given that a reference RFV = 100 represents the nutritive value of full-bloom alfalfa, assuming 41% ADF and 53% NDF (Karayilanli and Ayhan, 2016), the RFV observed at d 0 indicate forage nutritive value expressed as RFV that was greater than full-bloom alfalfa for the 3 forage species studied here. By d 28, RFV was equivalent to 100 for ARG, WHT, and VWR, but RFV decreased dramatically in all 3 forage species by d 56 to levels much less than the full-bloom alfalfa reference RFV.

A grazing year × forage species interaction was significant ($P = 0.02$) for CP (Table 3). No CP concentration differences ($P = 0.12$) were observed among forage species in 2015. However, in 2016, CP concentration of VWR was greater ($P = 0.01$) than that of WHT. The CP concentration of VWR in 2016 was also greater than the CP concentrations of VWR and ARG in 2015. There was also a date effect ($P < 0.01$) for CP, with concentrations decreasing as the grazing season progressed from 11.3 ± 0.4% at d 0 down to 8.5 ± 0.4% at d 28 and down more to 7.5 ± 0.4% at d 56. Decreasing CP concentrations with advancing forage maturity were anticipated and have been observed by others in cool-season annual and perennial forages.

Previous studies concluded that nutritive values of VWR were comparable to other cool-season perennial grasses such as orchardgrass (Sanderson et al., 2004b) and tall fescue (Bosworth et al., 1985). Nutritive values of VWR reported here are also within reported ranges of a related forage species, basin wildrye (*Elymus cinereus* Scribn. & Merr.; Bruce et al., 2012). These researchers noted CP values on a DM basis from 4.6 to 14.3% and ADF from 35.9 to 52.5%, relatively dramatic ranges in nutritive value, with reduced nutritive values associated with increasing maturity. The literature and present results suggest that VWR pastures are competitive with widely used cool-season grass alternatives in terms of nutritive value. As expected, VWR may be most nutrient dense earlier in the grazing season, and it is reasonable to postulate that greater grazing-animal growth rates could be supported during these periods.

ADG. There was no significant ($P = 0.09$) forage species × year effect for steer ADG (Table 3). Steer ADG was greater on ARG (1.40 ± 0.05 kg/steer per day) than on WHT (1.20 ± 0.05 kg/steer per day; $P < 0.01$) or VWR (1.26 ± 0.05 kg/steer per day; $P = 0.03$), and ADG between WHT and VWR were comparable ($P = 0.38$). In addition, there was a year effect ($P < 0.01$) for ADG. Steer ADG was greater in 2016 (1.51 ± 0.04 kg/steer per day) than in 2015 (1.07 ± 0.04 kg/steer per day). Steer ADG on ARG in the present experiment surpassed that reported in another experiment in North Mississippi in which steers gained 1.17 ± 0.03 kg/d grazing Marshall annual ryegrass from mid-April to early June (Parish et al., 2012). Whereas annual ryegrass is the predominant cool-season annual pasture grass in North Mississippi, tall fescue is the predominant cool-season perennial grass in this area. Previous studies at the same research site of steers grazing tall fescue reported spring (mid-March until early June) ADG values of 0.53 kg/steer per day on Kentucky-31 toxic endophyte-infected tall fescue and 0.91 to 1.02 kg/steer per day on various cultivars of AR584 nontoxic endophyte-infected tall fescue (Parish et al., 2013). Steer ADG for ARG, WHT, and VWR in the present experiment each exceeded that of tall fescue in this previous report. The steers in the previous and current studies were similar in BW, age, and breed composition and were managed in comparable continuous stocking systems. This suggests that ARG, WHT, and VWR are all reasonable alternatives to tall fescue for supporting good stocker calf grazing growth performance in North Mississippi. In a direct comparison of cool-season annual grasses and tall fescue, Beck et al. (2008) determined that calf ADG was not different during spring grazing among annual ryegrass, a combination of wheat and cereal rye, or Jesup AR542 nontoxic endophyte-infected tall fescue in one year but was greater on annual ryegrass than the other forages in another year. In this experiment BW gains ranged from 0.73 to 1.12 kg/d. Further, calf growth performance during autumn on the nontoxic endophyte-infected tall fescue exceeded that of the annual grasses in one year but was greater on the annual grasses in a consecutive year. Those results corroborate the observation in the present experiment of a year effect for ADG and suggest that environmental conditions influence animal growth performance on cool-season pastures to the extent that ADG rankings may change from one year to another. Others have documented that the calf ADG achieved grazing annual ryegrass in the Southeast United States are unsurmounted by alternative grasses. Researchers assessing small grains (including wheat) and annual ryegrass interseeded into bermudagrass [*Cynodon dactylon* (L.) Pers.] sod in southern Arkansas concluded that annual ryegrass was a necessary addition for calf grazing programs to achieve the greatest possible animal growth performance (Beck et al., 2007). In particular, spring ADG were boosted with annual ryegrass addition to pastures.

For grazing animals on pasture, forage nutritive value may set the upper limit for ADG and the herbage mass at which ADG no longer increases, whereas herbage mass determines the share of potential ADG that is realized (Sollenberger and Vanzant, 2011). In the present experiment, because herbage mass was not limiting for DMI, it is reasonable that subtle nutritive value advantages of ARG explain at least a proportion of the greater ADG on this forage species relative to VWR and WHT. The superior RFV at d 0 for ARG over VWR and WHT was the observable nutritive value advantage of ARG. However, it is plausible that there were DMI differences among forage species that contributed to this difference in steer growth performance; yet, this remains speculation only because forage DMI was not quantified in this experiment.

Nutritive Value. Mean forage nutritive values for Exp. 2 by year are presented in Table 4. Mean forage nutritive values pooled across years on a DM basis for ensiled forage were as follows: ARG (10.9% CP, 30.5% ADF, 48.3% aNDF, 63.5% TDN, and 126 RFV) and VWR (11.3% CP, 30.7% ADF, 53.7% aNDF, 62.0% TDN, and 113 RFV). Forage nutritive values also differed by year. In 2015 TDN ($P = 0.02$) and ADF ($P < 0.01$) were greater than in 2016 for both ARG and VWR. The aNDF of VWR was greater ($P = 0.03$) than that of ARG in both years.

Exp. 2: Forage Intake

There was a forage species × year effect ($P < 0.0001$) for mean daily DMI of ensiled forage by steers (initial BW 269.5 ± 6.4 kg) over 35-d periods in each of 2 yr (Exp. 2, Table 4). On a DM basis, steers offered ad libitum ensiled forage consumed comparable ($P = 0.90$) amounts of ARG (7.99 ± 0.14 kg/d) and VWR (7.88 ± 0.14 kg/d) in 2015. However, in 2016 steers consumed more ($P < 0.0001$) VWR (7.41 ± 0.14 kg/d) than ARG (6.19 ± 0.14 kg/d) ensiled forage despite no advantage in aNDF concentra-

Table 3. Mean forage CP on a DM basis and steer ADG as affected by forage species and grazing year[1]

	2015			2016				*P*-value		
Item	VWR	ARG	WHT	VWR	ARG	WHT	SEM	Year × forage species	Year	Forage species
CP, %	8.7[b]	8.4[b]	9.4[ab]	10.1[a]	9.6[ab]	8.7[b]	0.5	0.02	0.37	0.49
ADG, kg/d	0.96[c]	1.24[b]	1.01[c]	1.56[a]	1.57[a]	1.40[ab]	0.07	0.09	<0.01	<0.01

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Year: grazing years were April 8 to June 3, 2015, and April 6 to June 1, 2016. Forage species: VWR = Virginia wildrye; ARG = Marshall annual ryegrass; WHT = EK102 wheat.

Table 4. Mean ensiled forage nutritive value on a DM basis and steer DMI as affected by forage species and year[1]

	2015		2016			*P*-value		
Item	ARG	VWR	ARG	VWR	SEM	Year × forage species	Year	Forage species
TDN, %	65[a]	64[ab]	62[bc]	60[c]	1.0	0.20	0.02	0.02
aNDF,[2] %	48.2[b]	52.3[a]	48.4[b]	55.1[a]	1.4	0.39	0.03	0.03
ADF, %	33.1[a]	32.1[a]	27.9[b]	29.2[b]	1.1	0.41	<0.01	0.11
CP, %	11.6[a]	9.8[b]	10.1[b]	12.7[a]	0.6	0.29	0.08	0.83
Relative feed value	122[b]	114[c]	129[a]	112[c]	3.4	0.27	0.02	0.06
DMI, kg/d	7.99[a]	7.88[a]	6.19[c]	7.42[b]	0.14	<0.01	<0.01	<0.01

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Year: feeding periods in consecutive years were July 16 to August 19, 2015, and August 7 to September 10, 2016. Forage species: VWR = Virginia wildrye; ARG = Marshall annual ryegrass.

[2]aNDF = NDF treated with amylase and sodium sulfite.

tions to justify this result. Dry matter intake of VWR was less ($P = 0.02$) in 2016 than in 2015, and DMI of ARG was less ($P < 0.0001$) in 2016 than in 2015. Interestingly, forage nutritive values did not explain the forage intake differences observed. For example, the least DMI measured was for steers consuming ARG in 2016 relative to VWR in 2016 or any forage species in 2015. However, the aNDF value for ARG in 2016 was similar to that of ARG in 2015 and less than that of VWR in 2015 or 2016. It was expected that forage DMI would decrease as aNDF increased (Vazquez and Smith, 2000). The DMI values observed in the current experiment are comparable to the mean DMI ranging by residual feed intake quintile from 6.5 to 8.7 kg/d reported for beef heifers with a mean initial BW of 260 ± 21.6 kg (Damiran et al., 2018). The forage-based diet in the Damiran et al. (2018) experiment contained a 7:3 ratio of mixed smooth bromegrass (*Bromus inermis* Leyss.) and alfalfa (*Medicago sativa*) hay with rolled barley (*Hordeum vulgare*) grain.

Despite questions about the current lack of cost effectiveness of using VWR for beef cattle grazing due to its relatively high seed cost, it is incumbent upon researchers to determine whether there are production benefits to use of this forage that may offset initial establishment costs to warrant further exploration as a more widely used forage crop in the region. It can be used as either pasture or conserved forage for confinement feeding. Native grasses such as VWR are touted for their drought tolerance relative to many improved forage species (USDA, 2009). In that regard, conserving VWR as stored forage for feeding to cattle during periods of drought is a prospective use for VWR in cattle production systems that is worth exploring. In the present experiment, VWR use for feeding to cattle as stored forage during the warm-season forage production months was evaluated. Thus, VWR could serve as pasture for grazing during the cool-season and be fed as conserved forage outside of its active growing season to extend its use in forage-based cattle systems throughout the year.

IMPLICATIONS

There were few differences among ARG, WHT, and VWR for forage nutritive values with the exception of a CP advantage for VWR over WHT in one year and superior RFV for ARG in early April. Nutritive values generally decreased as the grazing season progressed toward the end of spring with advancing forage maturity. Steer ADG was greatest on ARG during spring grazing among these 3 cool-season grasses. Given the varying seasonal growth profiles of these forages, it would be useful for future research to assess these forages over a greater portion of the year including autumn and winter periods to gain a more comprehensive understanding of their potential contributions to grazing systems in the region. Questions remain, given the relatively expensive seed cost of VWR, as to the economics of replacing improved forages with this native grass species. Additionally, plant productivity and persistence over time need to be assessed to determine long-term effectiveness of using VWR in pasture settings.

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058 Virginia wildrye as an alternative to annual ryegrass and wheat for grazing stocker beef steers.

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The perennial grass, Virginia wildrye (*Elymus virginicus* L.) (WR), was evaluated as an alternative to two annual grasses, annual ryegrass (*Lolium multiflorum*) (ARG) and wheat (*Triticum aestivum*) (WHT), as pasture for grazing beef calves. Replicated (n = 3) 2.02-ha paddocks of WR, 'Marshall' ARG, and 'EK102' WHT monocultures were established in September 2014 in randomized design at the Mississippi Agricultural and Forestry Experiment Station Prairie Research Unit in Prairie, MS. The WR, ARG, and WHT seed were no-till drilled at seeding rates of 16.8, 33.6, and 112.1 kg/ha, respectively, into Houston clay soils. Each pasture received a 27.2 kg/ha application of actual nitrogen as ammonium nitrate in October 2014. Weaned Angus crossbred steer calves (n = 36, BW = 280.1 ± 5.5 kg) were stratified by BW and assigned into 9 groups of 4 calves. The steer groups were each randomly allocated to one of the pasture replications. Steers began continuous grazing of paddocks on April 8, 2015 for a 56-day period. All steers had unrestricted access to water and a complete loose mineral and vitamin supplement. Steers were weighed on two consecutive days at the start and end of grazing and at d 28 during the grazing period. Data were analyzed using PROC MIXED of SAS with $P < 0.05$ used to separate least square means. Steer ADG was greater ($P < 0.02$) for ARG (1.29 ± 0.08 kg/d) compared with WR (1.02 ± 0.08 kg/d). Steer ADG was not different ($P = 0.55$) between WR and WHT (1.08 ± 0.08 kg/d); nor was ADG different ($P = 0.07$) between ARG and WHT. Initial results suggest that, under a constant stocking rate, WR is comparable to WHT, but there is an ADG advantage for ARG over WR in stocker cattle during a spring grazing period. A second year of data collection will further evaluate steer growth performance grazing these various cool-season grasses.

Keywords: wildrye, annual ryegrass, wheat

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059 Distiller's grains as a substitute for fertilizer in summer grazing systems: performance, nitrogen recovery, and profit.

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Stocker cattle producers seek to maximize net income by optimizing inputs, and capturing more input nitrogen (N) from warm-season pasture systems may simultaneously improve income and reduce nitrogen runoff. Each summer for 4 yr, stocker cattle were grazed on 12 pastures of yellow bluestem (*Bothriochloa ischaemum*) to compare efficiency of N input types. Three pastures were assigned to each of 4 treatments. Control (CON) pastures were stocked at 318 ± 32 kg initial BW/ha and received minimal N inputs. The remaining nine pastures were stocked at 642 ± 36 kg initial BW/ha. Three of those pastures received corn distillers dried grains (DDGS) supplement at 0.75% of BW/d. Three other pastures were fertilized with 90 kg/ha of actual nitrogen as urea (N+), and the final three received nitrogen and 39 kg/ha actual phosphorus fertilizer (N+P). Stockers (239 ± 21 per yr; steers or heifers) were grazed for 109 ± 27 d, as adequate forage was available (grazing period and stocker sex was constant across pastures within year). Stockers in non-DDGS pastures received 0.45 kg/d of a 40% CP supplement plus monensin during the later half of the grazing season to meet their CP requirement. Response to treatment was modeled with yr as a random effect. DDGS pastures produced greater ADG, gain per hectare, and net return. Due to low stocking rate, CON pastures produced the least gain per ha; low inputs also resulted in greater N recovery in CON pastures. In this analysis, DDGS supplementation improved N recovery compared with fertilizer inputs, and DDGS was the most cost effective input, however stocker producers must continuously evaluate input options in response to market price fluctuations.

Table 059.

Item	CON	N+	N+P	DDGS	SEM
ADG, kg/d	0.86[a]	0.80[a]	0.86[a]	0.98[b]	0.128
Gain, kg/ha	115[a]	212[b]	228[b]	258[c]	23.9
N recovery[1], %	33[a]	6[b]	5[b]	17[c]	1.7
Return[2], $/ha	97[a]	213[b]	196[b]	306[c]	48.6

[1]Calculated as nitorgen (N) retention in steer gain per NRC (1996) divided by N inputs, including atmospheric nitrogen deposition.

[2]Gain/ha * $2.2/kg - (DDGS kg * $0.18/kg + N fertilizer kg * $1/kg + P fertilizer kg * $1.3/kg + 40% CP kg * $0.22/kg; as appropriate) - $150/ha.

[a,b,c]Within a row, means lacking a common superscript differ ($P < 0.05$).

Keywords: supplement, fertilizer, bluestem

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PHYSIOLOGY: PHYSIOLOGY I

060 Ergot alkaloid induced vasoconstriction of bovine uterine and ovarian blood vessels.

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Fescue toxicosis is a disease common in cattle grazing tall fescue (*Festuca arundinacea*) containing an endophytic fungus (*Epichloë coenophiala)* that produces ergot alkaloids. Ergot alkaloids cause vasoconstriction to the extremities, however it remains undetermined how blood flow to the reproductive organs are affected.

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Original Research Article

Economic and conservation implications of converting exotic forages to native warm-season grass

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ABSTRACT

Intensive agriculture can have negative environmental consequences such as nonpoint source pollution and the simplification of biotic communities, and land sharing posits that conservation can be enhanced by integrating agricultural productivity and biodiversity on the same land. In the Southeastern United States, native warm-season grasses (NWSG) may be a land sharing alternative to exotic forages currently in production because of greater livestock gains with lower fertilizer inputs, and habitat for grassland birds. However, uncertainty regarding costs and risk poses an important barrier to incorporating NWSG in livestock operations. We evaluated the economic and conservation implications of NWSG conversion among small, operational-scale pastures (6.8–10.5 ha) during 2011–2012 at the Prairie Research Unit in Monroe Co., Mississippi (USA). We used partial budgets to compare the marginal rate of return (MRR_e) from converting exotic grass pastures to either a NWSG monoculture of Indiangrass (*Sorghastrum nutans*) or a NWSG mix of Indiangrass, little bluestem (*Schizachyrium scoparium*), and big bluestem (*Andropogon gerardii*). We similarly compared changes in productivity of dickcissels (*Spiza americana*), a grassland bird specializing in tall structure. Average daily gain (ADG) of steers and revenue were consistently higher for NWSG treatments than exotic grass pasture, but ADG declined between years. Indiangrass pastures yielded consistently positive MRR_e, indicating producers would receive 16–24% return on investment. Marginal rate of return was lower for mixed NWSG (−12 to 3%), driven by slightly lower livestock ADG and higher establishment costs than for Indiangrass. Sensitivity analyses indicated that MRR_e also was influenced by cattle selling price. Conversely, mixed NWSG increased dickcissel productivity by a greater degree than Indiangrass per amount invested in NWSG conversion, suggesting a tradeoff between livestock and dickcissel production between the two NWSG treatments. Given continued increases in livestock prices, NWSG could be a sustainable land sharing alternative to exotic pastures currently in production, but subsidies and changes in management may be required for NWSG conversion to be viable for producers and to maintain conservation benefits.

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1. Introduction

Agricultural intensification supplies food to a growing human population by increasing productivity per unit of area through greater inputs of fertilizers, better crop protection, more efficient grazing systems, and other management practices and technologies (Matson et al., 1997; Tilman et al., 2001; Foley et al., 2005). Increases in food production are promoted as part of a conservation strategy known as land sparing, where one maximizes production on agricultural lands to avoid further conversion of natural areas to cultivation (Green et al., 2005; Phalan et al., 2011). However, environmental costs of intensive agriculture may be substantial, including nonpoint source pollution and reductions in the compositional and structural diversity of local vegetation which can negatively impact local biodiversity and production of ecosystem services such as pollination (Losey and Vaughan, 2006; Kleijn et al., 2009). Arguments in favor of land sparing often rely on the premise that reductions in agricultural productivity accompany biodiversity benefits from land sharing (using biodiversity-friendly practices with agriculture; e.g., Green et al., 2005; Phalan et al., 2011), and recent studies support this premise (e.g., Kleijn et al., 2009; Sabatier et al., 2010; Bateman et al., 2013; Mouysset et al., 2015). However, this paradigm may overlook agricultural practices that sustainably increase productivity, provide ecosystem services, and support wildlife (Tscharntke et al., 2012). Furthermore, much of the terrestrial land mass is altered by agriculture and forestry (Hurtt et al., 2006) yet may still be important sources of biodiversity (Pimentel et al., 1992). Developing agricultural practices that meet future increases in food demand without incurring additional environmental costs may be critical to avoiding further biodiversity loss (Matson et al., 1997; Askins et al., 2007; Tscharntke et al., 2012).

In the Southeastern United States, exotic forages such as bermudagrass (*Cynodon dactylon*) and tall fescue *(Schedonorus arundinaceus*) are widely established for beef production (Ball et al., 2007; Barnes et al., 2013), and pastures are often managed with high grazer densities and large inputs of fertilizer (Phillips and Coleman, 1995; Hoveland, 2000). However, high stocking rates and fertilizer use also may increase environmental costs via nonpoint source water and air pollution (Stout et al., 2000; Eickhout et al., 2006; Snyder et al., 2009; Liebig et al., 2010), and exotic grass pastures may negatively impact wildlife (Greenfield et al., 2002; Barnes et al., 2013; Martin et al., 2015; Monroe et al., 2016). Price of nitrogen-based fertilizers also can be highly volatile (Huang et al., 2009) and high fertilizer costs may negate any additional revenue generated by greater forage yield and quality from added nutrient inputs (Phillips and Coleman, 1995; Coleman et al., 2001; Deak et al., 2010).

A sustainable alternative to exotic forages may lie with native warm-season grasses (NWSG; Taylor, 2000; Harper et al., 2007). Varieties of NWSG species can be adapted to local growing conditions, can tolerate drought and poor soil conditions, and do not require heavy nutrient inputs to be productive (Jung et al., 1988; Brejda et al., 1995; Harper et al., 2007; Keyser et al., 2012). Furthermore, native forages may yield competitive livestock gains even when managed with fewer fertilizer inputs than exotic grasses (Phillips and Coleman, 1995; Gillen and Berg, 2001; Lowe et al., 2015; Keyser et al., 2016). Native forages also may offer benefits to wildlife such as grassland birds, whose populations exhibited steep declines during the 20th century (Sauer and Link, 2011). In contrast with the low, sod-forming structure of many exotic forages, native bunchgrasses may be readily used for nesting by certain grassland bird species (Hughes et al., 1999; Giuliano and Daves, 2002; Monroe, 2014).

Incorporating NWSG in cattle production thus has potential to improve sustainability and grassland bird conservation on private lands in the Southeastern U.S. However, NWSG conversion requires substantial costs from establishment and loss of revenue while pastures are taken out of production for 1–2 years. The possibility of not recovering these losses due to establishment failure, variation in market conditions, or weather presents risks for producers and may be a significant barrier to incorporating these grasses in livestock operations (Taylor, 2000; Doll and Jackson, 2009). Data on costs and benefits of NWSG conversion also are needed to inform distribution of cost-share and incentives to producers (Claassen et al., 2008). In northeastern Mississippi, we estimated greater productivity of dickcissels (*Spiza americana*), an obligate grassland bird and neotropical migrant, among pastures recently converted to NWSG compared with exotic forages (Monroe et al., 2016). We also estimated lower dickcissel productivity in grazed than non-grazed NWSG for this tall structure specialist, but grazing may offer producers the opportunity to recover costs from establishment and even increase their net benefits through greater livestock gains with reduced fertilizer costs than with exotic forages. Native warm-season grass pastures may thus be a land sharing alternative to set-aside programs such as the Conservation Reserve Program (CRP). We therefore conducted marginal analyses to evaluate the viability of NWSG using production costs and cattle gains from our study sites. We also conducted sensitivity analyses to evaluate the relative contribution of budget parameters to marginal rate of return. Finally, we used estimates of dickcissel productivity (Monroe et al., 2016) to determine the marginal rate of return for this grassland bird, and consequently the land sharing potential of NWSG pastures.

2. Materials and methods

2.1. Study site and experiment

We assigned 9 pastures (range = 6.8–10.5 ha) to one of three treatments replicated in three blocks at Mississippi State University's Prairie Research Unit (PRU) in Monroe Co., Mississippi, USA (lat 33°47′N, long 88°38′W). The 30-year average (recorded by a weather monitoring station in nearby Aberdeen, Mississippi; NOAA, 2017) for mean monthly precipitation and maximum temperature during the growing season (April–October, 1981–2010) was 104.8 mm and 28.8 °C, respectively.

Following herbicide treatment and prescribed fire (Appendix A), we seeded NWSG treatments in May 2008. Treatments included a mix of bermudagrass and tall fescue (hereafter, mixed exotic pasture); Indiangrass monoculture (*Sorghastrum nutans*, "Kentucky ecotype"; hereafter, Indiangrass pasture); and mixed NWSG pasture planted with big bluestem (*Andropogon gerardii*, "Kaw"), little bluestem (*Schizachyrium scoparium*, "Aldous"), and Indiangrass. We provide additional details on establishment in Appendix A.

During production years (2011 and 2012), we used typical management regimes for exotic or native pastures. For example, each spring we prescribed burned all native pastures prior to the addition of cattle (*Bos taurus*). Depending on soil conditions fertilizer may be necessary for NWSG pasture (Keyser et al., 2012; Harper et al., 2015), and following soil tests, we applied fertilizer once each spring at 33.6 kg ha^{-1} for native grass pastures and 67.3 kg ha^{-1} for mixed exotic pasture. In June 2012, we applied 2,4-D herbicide to all pastures at 2.56 L ha^{-1} to control competition from broadleaf forbs. We continuously stocked pastures (exotic and native) mid-May through September with fall-born Angus × Hereford steer calves (average initial body weight [BW]: 237 ± 22 kg in 2011 and 262 ± 33 kg in 2012) allotted to pastures by BW at a rate of 2.7 steer ha^{-1} (Mississippi State University Institutional Animal Care and Use Committee approval #11–039). We weighed un-fasted steers on two consecutive days when first allotted to pastures, and then similarly weighed steers when removed at the end of season, and we used two-day averages to characterize start and end weights of each steer. We also rounded up and weighed steers approximately once a month during the season. Additionally, mean monthly growing season precipitation was lower than the 30-year average in 2011 (101.6 mm) but not in 2012 (115.5 mm). However, total April–June precipitation was less in 2012 (194 mm) than 2011 (368 mm; NOAA, 2017), and in response to prolonged drought on 10–11 July 2012 we uniformly reduced stocking rates in each treatment (native and exotic) by one third.

2.2. Livestock gain analysis

Because the only source of revenue considered in this system was through livestock production, and the price received for cattle after the grazing season depends on their weight, we first estimated the rates of weight gain from each treatment. We used linear mixed models from the package *nlme* (Pinheiro and Bates, 2015) in R (version 3.2.3, R Development Core Team, 2015) to model effects of treatment and year on average daily gain (ADG; kg d^{-1}) of steers. We computed ADG for each animal by subtracting starting weights in May from end weights measured when we removed steers in September, then dividing by number of days grazed in each season (111 and 113 days in 2011 and 2012, respectively). Following Zuur et al. (2009), we began by fitting the most complex model, which included fixed effects of treatment, year, treatment × year, and a random effect of pasture. We used likelihood ratio tests to evaluate for more parsimonious models until dropping additional covariates did not improve fit. We report means and 95% confidence intervals (CI) of parameter estimates and ADG for each treatment and year. We similarly used linear mixed models and a single July weighing each year to estimate ADG for cattle removed in July 2012 (see *Study site and experiment*).

2.3. Budget analysis

We constructed partial enterprise budgets for each treatment by only including costs that varied among treatments, thus permitting calculation of the marginal rate of return (MRR_e) for converting mixed exotic pasture to NWSG (CIMMYT, 1988). For each NWSG treatment and year, we calculated marginal cost (difference in costs that vary between NWSG and mixed exotic pasture) and marginal net benefit (difference in net benefit between NWSG and mixed exotic pasture). Budgets excluded costs for pasture rent, fertilizer application (but not cost of fertilizer), procurement and marketing costs, and fixed costs such as depreciation and insurance, because these should be identical across treatments. Similarly, we applied herbicides equally to all pastures in June 2012 and therefore we excluded this cost from our budgets. We converted all costs and revenue to per ha basis and we used the United States Consumer Price Index to adjust prices for inflation to 2011 dollars (Bureau of Labor Statistics, 2017). We further describe the costs and revenue included in our budgets in Appendix A.

We calculated MRR_e for NWSG conversion (Indiangrass or mixed NWSG) by dividing the marginal net benefit by the marginal cost and converted this to a percentage:

$$MRR_e = \frac{NetBenefit_{NWSG} - NetBenefit_{Exotic}}{Cost_{NWSG} - Cost_{Exotic}} \times 100\%$$

The resulting value is interpreted as the additional benefit (after recovering investment in NWSG conversion) that the enterprise would receive relative to mixed exotic pasture (CIMMYT, 1988). We also conducted sensitivity analyses by varying individual parameters in each partial budget by ± 10% and monitoring change in MRR_e for Indiangrass pasture and mixed NWSG, thus evaluating the relative importance of these parameters. We used prices and rates from 2011 as a baseline scenario, and parameters that vary included January selling price, ADG, fertilizer price, seed prices, prescribed fire costs, and interest rates. We also tested the response of MRR_e to establishment costs of Indiangrass pasture and mixed NWSG (before being prorated) because variation in establishment success determines the final price paid for establishment.

Additionally, cattle prices may have a large influence on profitability of a grazing enterprise (Manley et al., 1997), and it is useful to examine how changes in price might affect MRR_e beyond the two years of our study. We therefore calculated MRR_e from NWSG conversion for the previous 15 years using our 2011 partial budget as a baseline, May price paid (2001–2015), and

January price received (2002–2016; NASS, 2017). We then examined the number of years that NWSG conversion yielded a positive MRR_e, and calculated the breakeven value for price received.

2.4. Avian response

Previously, we used a multi-state capture-recapture model in a Bayesian framework to estimate dickcissel productivity from nest monitoring, female nest attendance, and brood size while accounting for treatment-specific variation in survival and detectability (Monroe et al., 2016). During May–July in 2011 and 2012, we found and monitored dickcissel nests in each pasture using methods approved by the MSU IACUC (approval #11–020; described in Monroe et al., 2016). We used these dickcissel productivity estimates to evaluate conservation benefits by comparing their relative value with respect to NWSG conversion (Musters et al., 2001). We again used a partial budget approach, this time replacing the financial net benefit with treatment-specific dickcissel productivity estimates (fledglings ha^{-1}), and dividing the marginal net benefit (difference in productivity between NWSG and mixed exotic pasture) by the marginal cost to yield a marginal rate of return in dickcissel productivity (MRR_d):

$$MRR_d = \frac{Fledglings_{NWSG} - Fledglings_{Exotic}}{Cost_{NWSG} - Cost_{Exotic}} \times \frac{100}{100}$$

We interpreted this value as the change in dickcissel productivity for every $100 invested in NWSG conversion. Using the posterior samples of productivity estimates for each treatment obtained from our analysis in a Bayesian framework (Monroe et al., 2016), we report mean estimates of MRR_d, 95% credible intervals (CrI), and evaluated whether MRR_d differed from 0 by computing the proportion of iterations where MRR_d was greater than 0 (e.g., $Pr[MRR_{d,\ INDG} > 0]$). In a Bayesian framework, this becomes a probability statement where, for example, a value of 0.95 indicates a 95% probability that the MRR_d of Indiangrass pasture was greater than 0, suggesting strong support for a positive MRR_d for this treatment.

3. Results

3.1. Average daily gain analysis

For May–September ADG, we analyzed start and final weights from 360 steers over the two study years. Likelihood ratio tests did not indicated support for effect of treatment × year ($L = 3.60$, $df = 2$, $P = 0.17$), but dropping treatment ($L = 13.07$, $df = 2$, $P = 0.002$) or year ($L = 51.58$, $df = 1$, $P < 0.001$) did not improve fit. Overall, ADG was lower in 2012 than in 2011 ($\beta = -0.13$, 95% CI = −0.17, −0.10). Within years, ADG was similar between NWSG treatments, whereas ADG for mixed exotic pasture was 33–42% and 31–40% lower than Indiangrass pasture and mixed NWSG, respectively (Table 1). Analysis of ADG for May–July ($n = 448$ steers) did not support effect of treatment × year interaction ($L = 3.08$, $df = 2$, $P = 0.21$) or year ($L = 2.48$, $df = 1$, $P = 0.12$), but did support treatment effect ($L = 19.68$, $df = 2$, $P = <0.001$). Average daily gain was again similar between native grass treatments, whereas ADG for mixed exotic pasture was 34% and 25% lower for mixed exotic pasture than Indiangrass pasture and mixed NWSG, respectively (Table 1).

3.2. Budget analysis

Establishment cost was 11% greater for mixed NWSG ($888.95 ha^{-1}) than Indiangrass pasture ($803.94 ha^{-1}), driven by higher cost of pure live seed for the native grass mix (Table S1 in Appendix A). When prorated over ten years, establishment cost per annum was $117.94 ha^{-1} for mixed NWSG and $106.66 ha^{-1} for Indiangrass pasture. In contrast, initial maintenance cost for mixed exotic pasture incurred a prorated annual cost of $17.69 ha^{-1}. Both years, all treatments received positive net benefits from operations, although net benefits declined by >75% from 2011 to 2012 (Table 2). Despite this decline in net benefits, Indiangrass pasture yielded positive MRR_e both years, whereas MRR_e for mixed NWSG was slight in 2011, and negative in 2012 (Fig. 1). The lower MRR_e for mixed NWSG compared to Indiangrass pasture was likely due to a combination of slightly lower ADG (Table 1) and higher establishment costs. Additionally in 2012, MRR_e was reduced by heavier starting weights and 18% higher spring purchase price for cattle but only a 5% increase in price received in the fall (Fig. 2a). Price of

Table 1
Mean average daily gain (kg d^{-1}, and 95% confidence intervals) estimated from linear mixed models by year, removal month, and treatment for steers at the MSU Prairie Research Unit in Prairie, Mississippi, USA.

Year	Month	Mixed Exotic	Indiangrass	Mixed NWSG
2011	September	0.42 (0.34–0.49)	0.63 (0.56–0.71)	0.61 (0.54–0.68)
2012	September	0.29 (0.21–0.36)	0.50 (0.42–0.58)	0.48 (0.40–0.55)
Pooled[a]	July	0.57 (0.49–0.64)	0.87 (0.79–0.94)	0.76 (0.69–0.84)

[a] Effect of year was not supported for July average daily gain models, so we pooled estimates across years.

Table 2
Costs and revenue (\$ ha^{-1}) from partial enterprise budgets used to calculate marginal rate of return from conversion of mixed exotic pasture to Indiangrass or mixed NWSG at the MSU Prairie Research Unit, Mississippi, USA.

Treatment	2011			2012		
	Cost	Revenue	Net benefit	Cost	Revenue	Net benefit
Mixed Exotic	1861.72	3075.18	1213.46	2395.46	2673.88	278.41
Indiangrass	1991.83	3236.93	1245.10	2507.36	2803.64	296.28
Mixed NWSG	2003.80	3221.41	1217.61	2511.79	2775.90	264.11

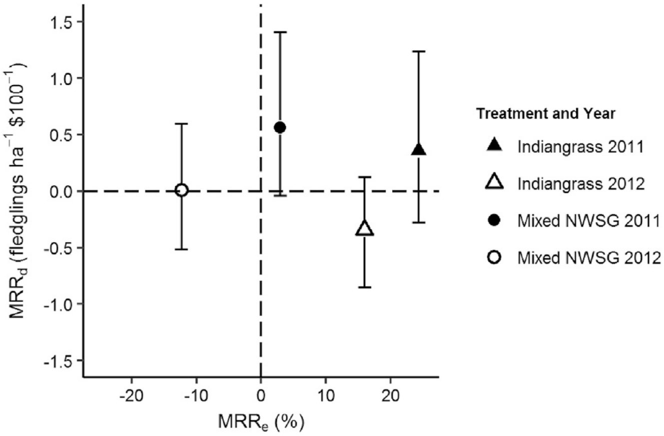

Fig. 1. Marginal rate of return on dickcissel productivity (MRR_d) and economic marginal rate of return (MRR_e) estimated for Indiangrass and mixed native warm-season grass (NWSG) treatments established at the MSU Prairie Research Unit, Mississippi, USA (2011–2012).

ammonium nitrate (fertilizer) also was 5% higher in 2012 than 2011 (Table S1 in Appendix A). Sensitivity analyses indicated that ADG and selling price were important contributors to changes in MRR_e for mixed NWSG and Indiangrass, with approximately 10% increase in MRR_e from a 10% increase in ADG or selling price (Table 3). Decreasing cost of establishment also had a comparable effect on MRR_e. Fertilizer, seed, and interest rates had relatively small effects on MRR_e.

During 2002–2016, price received in January for steers ranged from \$1.75 kg^{-1} in 2002 to \$3.10 kg^{-1} in 2015 (Fig. 2a) and was consistently lower than price paid the previous May except for 2013–2014. Assuming all other values were constant from the 2011 partial enterprise budget, Indiangrass pasture would yield a positive MRR_e for the last 7 of 15 years under consideration (Fig. 2b). The breakeven selling price (based on 2011 baseline budget) was \$2.02 kg^{-1} (or \$107.32 cwt^{-1}), and MRR_e was positive for steers grazing Indiangrass each year that selling price was at or above this value. Conversely, MRR_e from mixed NWSG was positive for 4 of 15 years under consideration (Fig. 2c), and the breakeven selling price for this treatment was \$2.18 kg^{-1} (or \$110.62 cwt^{-1}).

3.3. *Avian response to investment*

Dickcissel productivity in 2011 was higher in mixed NWSG than mixed exotic pasture whereas Indiangrass was intermediate (Table 4; Monroe et al., 2016). As a result, dickcissel productivity in mixed NWSG increased for every \$100 invested ($Pr[MRR_{d,\ MNWG} > 0] = 0.97$), whereas Indiangrass pasture increased productivity but to a lesser degree for the same investment ($Pr[MRR_{d,\ INDG} > 0] = 0.86$; Fig. 1). The following year, productivity declined among NWSG treatments but not for mixed exotic pasture (Table 4; Monroe et al., 2016). This led to a negative MRR_d for every \$100 investment in Indiangrass ($Pr[MRR_{d,\ INDG} > 0] = 0.06$), whereas mixed NWSG yielded no increase in productivity relative to mixed exotic pasture ($Pr[MRR_{d,\ MNWG} > 0] = 0.48$; Fig. 1).

4. Discussion

Native warm-season grasses (NWSG) hold promise of a sustainable alternative to exotic grass pastures currently in production through greater cattle weight gains with lower fertilizer inputs (Taylor, 2000; Harper et al., 2007; Holcomb et al., 2012), yet the costs and risks associated with establishment may be a significant barrier to producers. In this study we evaluated whether conversion to NWSG could increase marginal net benefits over exotic forages after accounting for initial establishment costs, and we assessed the benefits for an avian species as a land sharing approach to conservation given these additional costs. In both NWSG treatments we estimated higher average daily gain (ADG) of steers with lower fertilizer costs than exotic grass pastures, yielding greater revenue for these treatments than the alternative currently in production. This

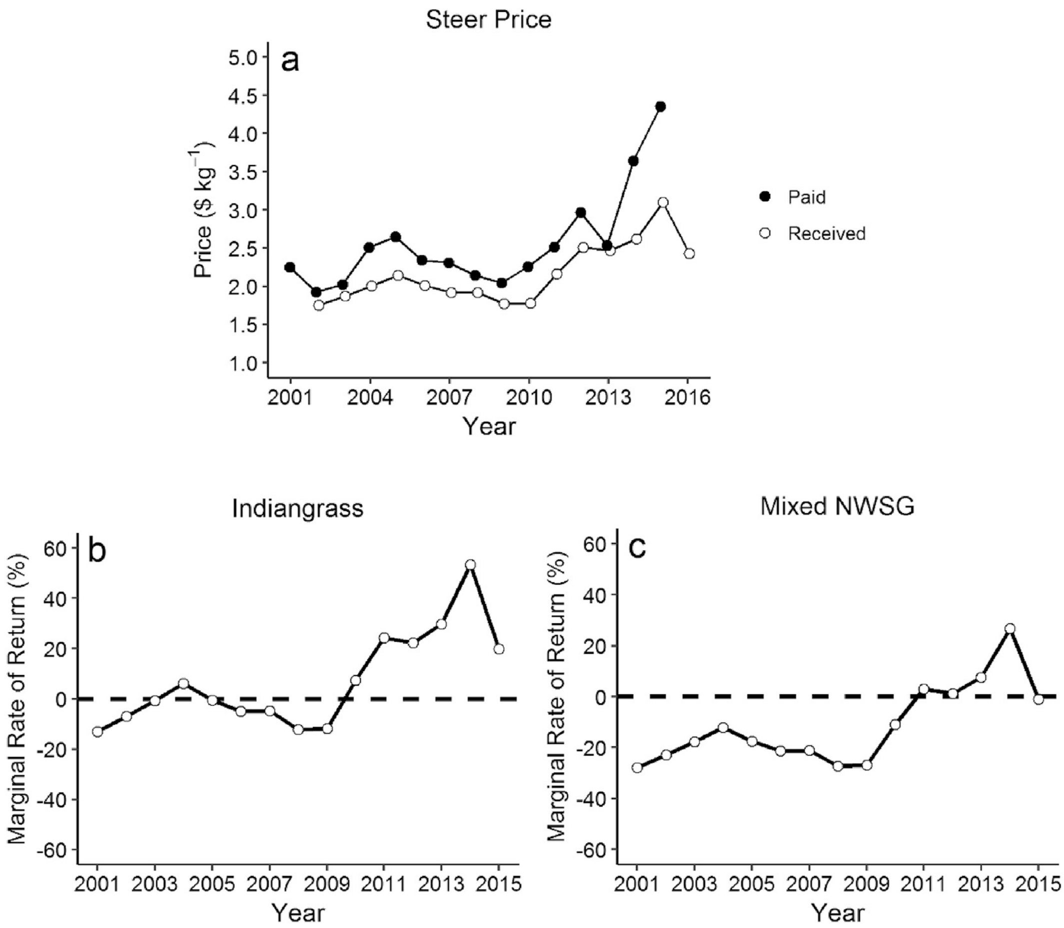

Fig. 2. Price paid in May (2001–2015) and price received in January (2002–2016) for steers (a), and corresponding economic marginal rate of return for converting mixed exotic pasture to Indiangrass (b) and mixed NWSG (c), given 2011 partial budget values.

Table 3
Sensitivity analysis[a] of economic marginal rate of return (MRR_e) from conversion of mixed exotic pasture to Indiangrass or mixed NWSG.

Parameter	Baseline value	10% decrease		10% increase	
		Indiangrass	Mixed NWSG	Indiangrass	Mixed NWSG
Selling Price	2.51 ($ kg^{-1})	−12.4	−9.7	12.4	11.0
ADG[b]	0.63, 0.61 (kg day^{-1})	−12.4	−10.2	12.4	10.2
Seed[b]	268.23, 349.98 ($ ha^{-1})	3.6	3.6	−3.4	−3.4
Prescribed fire	51.64 ($ ha^{-1})	6.2	4.7	−5.7	−4.3
Fertilizer	1.31 ($ kg^{-1} ha^{-1})	−1.8	−1.4	1.8	1.4
Interest	8%	3.9	3.3	−3.7	−3.2
Establishment[b]	803.94, 888.95 ($ ha^{-1})	11.1	9.3	−9.4	−7.9

[a] We conducted sensitivity analysis by varying 2011 partial budget parameters (±10%) and quantifying the difference (%) between the new MRR_e and the baseline MRR_e for each treatment.
[b] Baseline values are reported for Indiangrass and mixed NWSG, respectively.

Table 4
Marginal costs ($ ha^{-1}, difference in costs that vary between NWSG and mixed exotic pasture) and benefit (fledglings ha^{-1}, difference in dickcissel productivity, with 95% credible intervals[a]) used to calculate marginal rate of return in dickcissel productivity (MRR_d) at the MSU Prairie Research Unit, Mississippi, USA.

Treatment	2011		2012	
	Marginal Cost	Marginal Benefit	Marginal Cost	Marginal Benefit
Indiangrass	130.11	0.47 (−0.36, 1.60)	111.90	−0.38 (−0.95, 0.14)
Mixed NWSG	142.08	0.80 (−0.06, 2.00)	116.33	0.01 (−0.60, 0.69)

[a] We used dickcissel productivity estimates from Monroe et al. (2016).

conforms to previous studies finding that greater weight gains from native grass pasture can increase profitability of these systems over exotic grass pasture (Coleman et al., 2001; Gillen and Berg, 2001). However, lower ADG and greater starting weights and spring purchase price in the second year increased costs and reduced revenue, resulting in a lower marginal rate of return (MRR_e) for both treatments. For mixed NWSG, with somewhat higher establishment costs and lower ADG than Indiangrass, there was a slight return on investment in the first year, and a negative MRR_e the second year. In contrast, we estimated a greater increase in dickcissel productivity per unit investment for mixed NWSG than Indiangrass, indicating a trade-off in economic and conservation value between the two NWSG treatments.

The comparative advantage of NWSG pastures over mixed exotic pasture was primarily from higher ADG. In a parallel study of our pastures (Oloyede, 2013), nutritional analyses of forages indicated crude protein and digestibility were highest among mixed exotic pastures, likely a response to greater fertilizer rates. However, dry matter yield was higher among native grass pastures, especially for Indiangrass during peak production (July), and therefore forage availability rather than quality may explain observed differences in ADG among treatments. Steer gains measured in our study were consistent with rates measured for big bluestem-Indiangrass without fertilizer (0.54 kg d^{-1}; Keyser et al., 2016) but less than rates reported in other studies with higher fertilizer inputs (0.82–96 kg d^{-1}; Burns and Fisher, 2013; Lowe et al., 2015). Average daily gain estimated for mixed exotic pasture in 2011 was comparable with gains reported previously for bermudagrass with higher stocking rates but also with greater nutrient inputs (Burns et al., 1984; Burns and Fisher, 2008, 2013). Dry matter consumption was lowest for steers in the mixed exotic treatment during June and July (Oloyede, 2013), and it is possible that dormant tall fescue limited forage availability during hot summer months. Nevertheless, the warm and dry conditions during our study years should favor bermudagrass production over tall fescue (Ball et al., 2007). Bermudagrass-tall fescue pastures also are found across the Southeastern United States (Ball et al., 2007) and therefore this treatment was a useful comparison with NWSG pasture.

Importance of forage availability is also illustrated by the reduction in ADG that coincided with drought in 2012. Drought reduces profitability of grazing enterprises (Dunn et al., 2010), and all treatments yielded lower net benefits in 2012 than in 2011. Adaptations to low moisture availability is touted as a potential benefit for native warm-season grasses due to their deep root growth (Harper et al., 2007). However, in our study the effect of drought on ADG seemed to be similar among NWSG and mixed exotic pasture because a treatment × year interaction for ADG was not supported. The similar responses to drought may reflect the recent establishment of NWSG pastures, drought tolerance of bermudagrass (Ball et al., 2007), and the relatively dry conditions of both years of our study, preventing us from quantifying the response of forages to the full range of precipitation experienced in this region.

Price of nitrogen fertilizer may affect rates of return for NWSG conversion (Holcomb et al., 2012), and we found a positive effect of nitrogen prices on MRR_e. Mixed exotic pasture received twice the amount of fertilizer as native pastures, and as fertilizer prices increased, the difference in cost between mixed exotic pasture and NWSG also increased, resulting in a higher MRR_e for native pastures. However, sensitivity analyses indicated that at the rates evaluated in this study, the response to fertilizer prices was relatively small and benefits from increased ADG due to NWSG conversion surpassed potential savings from reduced fertilizer costs. One study of fescue-bermudagrass pastures demonstrated that higher gains could be achieved at higher stocking rates with annual fertilizer applications up to 4.6 times greater than in our study (Franzluebbers et al., 2012). Applying fertilizer at such rates would increase fertilizer costs for mixed exotic pasture from \$36–38 ha^{-1} to \$164–172 ha^{-1}, which approaches the \$186–196 ha^{-1} from maintenance and prorated establishment costs of NWSG pastures. Although increased stocking rates in exotic grass treatments could produce total gain ha^{-1} equivalent to native grass pasture, such stocking rates also may incur higher production costs, making native grass systems more profitable overall (Phillips and Coleman, 1995; Coleman et al., 2001; Gillen and Berg, 2001). High stocking rates also expose producers to greater risk from variability in weather (Parsch et al., 1997) and prices of cattle (Manley et al., 1997) and fertilizer (Huang et al., 2009).

Importance of ADG and selling price also suggests that the advantage of NWSG conversion over current production from exotic forages may be highly dependent on external factors such as beef markets and weather. When we calculated MRR_e using 2011 baseline values while varying price paid and received, MRR_e for Indiangrass and mixed NWSG was positive for six and four of the last six years under consideration (2010–2015), respectively. If trends of higher beef prices persist there is a high likelihood that conversion to either Indiangrass or mixed NWSG would yield a positive MRR_e. Marginal rate of return also was sensitive to establishment costs, and establishment success may vary due to precipitation (Bakker et al., 2003) and control of exotic warm-season grasses (Barnes, 2004). Persistence of NWSG pastures also may depend on management and weather (Jackson et al., 2010). In our study the incomplete eradication of bermudagrass followed by disturbance from grazing and dry weather likely facilitated the spread of this grass in native pastures (Monroe et al., In press). We assumed that NWSG pastures would last at least 10 years when we prorated interest on establishment costs, but continuation of this study in subsequent years may have incurred additional costs for herbicide treatment and removing NWSG pastures from production for recovery. Sensitivity of NWSG to overgrazing (Mousel et al., 2003; Harper et al., 2007; Chamberlain et al., 2012) also suggests greater attention is needed for proper grazing management to maintain stand condition (and thus investment) than with exotic forages. Our results illustrate several important potential sources of risk that producers should consider when investing in NWSG conversion.

Whereas lower establishment costs and slightly higher ADG for Indiangrass led to a higher MRR_e for this treatment, MRR on dickcissel productivity was consistently higher for mixed NWSG. In 2011, both treatments yielded positive MRR_d, likely because the tall structure of NWSG bunchgrasses provides nesting substrate (Hughes et al., 1999; Giuliano and Daves, 2002; Monroe, 2014) whereas the low stoloniferous growth of bermudagrass may limit nesting opportunities dickcissels. The following year, dickcissel productivity declined among NWSG pastures and was actually somewhat lower in Indiangrass than mixed exotic pasture (Monroe et al., 2016), leading to a negative MRR_d for this treatment. Livestock management may have contributed to the decline in net productivity between years because dickcissel productivity remained constant in non-grazed mixed NWSG during our study (Monroe et al., 2016). This decline in dickcissel productivity suggests producers may need to adjust grazing practices to maintain suitable nesting habitat for species such as dickcissels. For example, although we employed continuous, season-long grazing, producers may choose to reduce stocking rates, defer grazing, or rest pastures, which could maintain structure of NWSG (Mousel et al., 2003; Chamberlain et al., 2012; Harper et al., 2015). We also managed NWSG with prescribed fire each spring to reduce inter-year variability of management in our two-year study, but grazing without fire (Rahmig et al., 2009) or varying the application of fire in patches over space and time (Davis et al., 2016) also may create suitable nesting vegetation for dickcissels. However, these practices should be considered with their respective costs and revenues to determine how they compare with MRR_e and MRR_d in our study.

Based on our sensitivity analyses, subsidies aimed at promoting grassland birds such as dickcissels should seek to offset higher establishment costs of mixed NWSG, and reduce the comparative advantage from slightly higher ADG with Indiangrass while considering variable livestock prices. Higher MRR_d for mixed NWSG also indicates dickcissel fledglings are relatively less expensive to produce than with Indiangrass. In other words, a greater investment in Indiangrass (through a larger area converted from mixed exotic pasture) would be required to increase dickcissel productivity to the same degree as mixed NWSG. Interpreted from this perspective presents a shift from payment for actions towards payment for results. Instead of mandating a specific management regime, result-oriented payments could be offered to producers for specific outcomes such as for number of nests found and protected (Musters et al., 2001). For example, if producers managing NWSG grazing are compensated for each dickcissel nest (or fledgling produced) in their pasture, they may be further motivated to reduce stocking rates during drought to maintain tall cover and abundance of potential nest sites. However, ability of landowners or monitoring agencies to effectively and efficiently estimate nest density and productivity remains a significant challenge in using such indices for result-oriented payments (Matzdorf et al., 2008; Burton and Schwarz, 2013).

Caution is warranted when interpreting our economic analyses in absolute terms (rather than relative to the alternative treatments considered) because these results depend largely on the assumptions and prices used in our partial enterprise budgets. However, another study in Tennessee using complete (instead of partial) enterprise budgets found NWSG forages were profitable, even when accounting for establishment costs (Lowe et al., 2015). Our inferences also are limited by the spatial and temporal scope of our study, and extensions of our approach could involve the use dynamic models that allow for varying producer decisions in response to changes in weather and markets (e.g., Sabatier et al., 2010; Mouysset et al., 2015). Similarly, we assumed steers were purchased in late spring for summer grazing, but other management scenarios could include grazing cattle during winter and spring when cool-season grasses are active. Conservation benefits of NWSG also could be evaluated in the context of the broader landscape (Armsworth et al., 2006; Drechsler and Wätzold, 2017). Additionally, it is important to acknowledge that our assessment of the conservation benefits from NWSG conversion depended strongly on our selection of dickcissels (Fischer et al., 2014), a tall structure specialist. Thus, the conservation implications we present are relevant to other species with similar preferences in habitat such as Henslow's sparrow (*Ammodramus henslowii*; Zimmerman, 1988; Winter, 1999), but NWSG conversion may yield the opposite response from grasshopper sparrows (*A. savannarum*) that may favor reduced vegetation structure and exotic grass stands (McCoy et al., 2001; Jacobs et al., 2012; Hovick et al., 2012). Evaluating response of other biodiversity measures to NWSG establishment and management relative to exotic pastures currently in production also may better inform policies to promote grassland bird habitat in working landscapes (Mouysset et al., 2014).

Given the extent of agricultural landscapes across the globe (Hurtt et al., 2006), incorporating biodiversity-friendly practices in agriculture through land sharing could have important implications for conservation, yet these practices may reduce agricultural productivity (Groot et al., 2007; Sabatier et al., 2010; Bateman et al., 2013; Mouysset et al., 2015) and conservation policy is often directed towards compensating producers for their loss (Musters et al., 2001; Burton and Schwarz, 2013). Our study suggests that at equivalent stocking rates NWSG pastures may yield greater livestock gains than exotic forages despite reduced fertilizer inputs, and the additional benefit for dickcissels suggests a win for both producers and conservationists. Converting exotic pastures to NWSG may offer a land sharing opportunity by increasing the sustainability and conservation value of private lands, permitting continued use for livestock production that could allow landowners to recover the cost of their investment. Still, variability in market factors and weather suggests subsidies and changes in management may be required to ensure that NWSG conversion is viable for producers and that conservation benefits are sustained.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.gecco.2017.04.006.

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